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ARTES SCIENTIA VERITAS

# A FIELD MANUAL
FOR
# RAILROAD ENGINEERS

BY

ames
## J. C. NAGLE, M.A., C.E., M.C.E.
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# PREFACE TO THE THIRD EDITION.

NEARLY twenty years ago the first edition of this manual was issued. Except for minor corrections, and the addition of Tables XXVIII and XXIX, in the second edition, less than two years later, no changes have since been made. For several years the author has had a general revision in contemplation, but other and more pressing calls have prevented this. As finally made, the revision covers more than was intended when it was begun, but falls short of what it should be, and has been done in a fragmentary manner. It is hoped, however, that the usefulness of the book has been increased.

Considerable new matter has been added to Chapter V. In order to conform to present practice, formulas have been derived for the conditions of straight frogs and switch points. Some engineers prefer the more approximate treatment, in which both switch-rails and frogs are assumed to be curved, and certainly the formulas are simpler and easier of application. For those who prefer it, the old method has been retained in large part. One may take his choice of methods.

A brief treatment of the mass-curve in connection with overhaul has been inserted, and the subject of grades has been amplified. Scattered through the text numerous other changes, additions, and omissions have been made.

A number of new tables have been incorporated in the text, and to the tables in the back of the book have been added Table I*a*, Radii of Metric Curves; Table IX*a*, Correction Factors for Use with Table IX; and Table XXX, The True Meridian and the Magnetic Declination. Table XIX has been extended to show volumes per 100-foot lengths of Prismoids for heights varying by tenths of a foot, up to fifteen feet. Soon after the first edition appeared, considerably more than this was suggested by Mr. R. A. Thompson, now a member of the

Engineering Board of the Interstate Commerce Commission, but the author side-stepped then—and before the new table was half finished wished that he had continued to do so.

Many helpful suggestions have been derived from the following works: "Modern Location of Standard Turnouts," by Kurtz; "Railroad Surveying," by Pickles and Wiley; "Railroad Curves and Earth-work," by Allen; "Field Engineering," by Searles and Ives; "Track Formulæ and Tables," by Roberts; "Railroad Construction," by Webb; "American Railway Engineering Association Manual," Edition of 1911. Acknowledgment for suggestions is here made.

Acknowledgments are also due many engineers who have suggested additions from time to time, many of which have been incorporated. Had all been included this would no longer be a handbook.

Special acknowledgments are due Mr. C. M. Kurtz for many suggestions in addition to those derived from his excellent handbook. Table IX*a* has been inserted at his instance, and a part of it is his work. Table XXX is also due to his suggestion. The section on land-line ties is his, and likewise the problem shown in Fig. 131. The treatment in connection therewith was suggested by him. Mr. A. C. Love, Professor of Railway Engineering in the Agricultural and Mechanical College of Texas, also made many useful suggestions, particularly in connection with transition-curves and the mass-curve. Formula $(172)_1$ was supplied by him.

J. C. NAGLE.

AUSTIN, TEXAS,
February, 1917.

# PREFACE TO THE FIRST EDITION.

EASE of reference and uniformity of notation are essential in a book that is to be consulted in the field. With this in mind an effort has been made in the following pages to secure a systematic arrangement of the subject-matter and uniformity of terms and notation. Except for a few cases Greek letters have been avoided and a single letter is used to designate an angle. In so far as practicable each figure is intended to be self-explanatory, so that the explanations necessary in connection with the problems have been reduced to a minimum. Algebraic equations stand each in a distinct line, thus rendering them more easily read.

A knowledge of the elements of geometry and trigonometry has been assumed, and only in the derivation of a few formulas in connection with the theory of transition-curves will any higher mathematics be needed. But these formulas may be accepted by the reader who is unfamiliar with the calculus without in any way affecting his ability to understand their applications or to follow subsequent reasoning.

One can most readily turn to what he wants in a book after having become familiar with its contents in the classroom. Keeping this in mind this book has been written so that it may be used as a text as well as for reference in the field. Wherever practicable solutions to problems have been given in a rigid, general form, followed by illustrative examples, so that the student need not lose sight of the principle involved while following the solution for a particular case. Wherever approximate solutions seemed preferable they have also been given and their limitations pointed out.

Free use has been made of the Table of Functions of a One-degree Curve, thus reducing the labor of field computations. By defining the degree of curve with reference to short chords for sharp curves—and, with tables of Radii, Long Chords, Mid-ordinates, etc., based on appropriate equations—the errors resulting from assuming the radius to vary inversely with the degree of curve will generally be found to be quite small.

Chapter I gives briefly the general method of making Reconnoissance; Chapter II treats of Preliminary Surveys; while Chapter III relates to Location.

Chapter IV, on Transition-curves, follows the method adopted by Professor Crandall, and enables one to locate the transition-curve with rigid accuracy where such is necessary. Approximate methods are also given by means of which the curve may be as easily located as any of the more limited easement curves ordinarily met with.

Chapter V, on Frogs and Switches, contains all that is necessary for their location. The formulas have been arranged to give the desired quantities in terms of the frog number whenever the resulting equations would be easier of application than the trigonometric ones usually given. The turnout tables are unusually full and give not only the theoretical lead but the stub lead as well, from which the practical lead can be at once found when the length of switch-rail is known.

Chapter VI, on Construction, tells how to set slope-stakes, and gives simple methods for computing areas and volumes either directly or by the use of tables. A short table of prismoidal corrections is given for end sections level, and also a formula for three-level sections, by means of which a suitable table may be computed if desired.

The tables at the end of this book have been arranged with a view to ease of reference, for, whatever the character of the text, the chief value of a field-book must depend upon the ease with which the tables may be consulted and upon their extent and accuracy. Table IX—Functions of a One-degree Curve—separates the logarithmic functions on the one side from the natural functions on the other and will be of assistance in locating these tables. Table XVI—Transition-curve Table—reading lengthwise of the page, likewise serves to separate the trigonometric tables from the miscellaneous tables that follow.

Some engineers object to the use of logarithmic tables in the field, but for them the natural functions are at hand; while for those who prefer logarithms the five-place tables of logarithmic sines, cosines, etc., will be found easy to consult and interpolate between.

All trigonometric tables are five-place, and others were carried to as many decimal places as their character demanded.

Tables I, III, IV, and V have been computed to agree with the definition of the degree of curve requiring curves sharper than 7° to be run with chords less than 100 feet in length, as described in the text. Tables XVII and XVIII were also computed expressly for this book.

Tables VI and XXVII are from electrotypes from Carhart's *Field Book for Civil Engineers* and were furnished by Ginn & Co. Electrotypes of Tables II, X, XII, XIII, XIX, XX, XXIV, XXV, XXVI, and also XVI — this last being from Crandall's book, *The Transition Curve*—were furnished by John Wiley & Sons.

Of the others, some were arranged from standard tables and others adapted in part and extended to increase their usefulness.

It will be noticed that vertical lines have been omitted wherever practicable, thus rendering it easier to refer to the tables.

Acknowledgments are due my associate, Professor D. W. Spence, for aid in making the tabular computations and in reading proof.

J. C. NAGLE.

COLLEGE STATION, TEXAS, May, 1897.

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# A FIELD-MANUAL FOR RAILROAD ENGINEERS.

## CHAPTER I.

## *RECONNOISSANCE.*

### ARTICLE 1. OBJECTS OF RECONNOISSANCE—HOW MADE.

**1.** THE question of the selection of the proper route for a line of railway is essentially an economic one, involving not only the cost of construction, but of maintenance and operation, and a consideration of the immediate and future traffic likely to pass over the completed road.

The engineer upon whom devolves the duty of making the surveys for a railroad is not often called upon to determine whether it should or should not be built, though his preliminary estimate may decide those whose duty it is to do so: the problem confronting him is *how to secure the best line, answering a given purpose, for the least cost.* Keeping in mind the proper working of the completed road, the problem may be divided into two general parts:

*First.* The selection of the general route between terminal points, and in some cases the selection of the terminals themselves.

*Second.* The fitting of the line to the ground in such a manner as will render the cost of constructing and operating the road a minimum.

The first is by far the more important and difficult operation, requiring the highest grade of engineering skill—a fact too seldom recognized by those selecting engineers for this work. The acquirement of the necessary skill can result only from long practice and close observation, coupled with the ability to fully grasp and weigh all the complex features of the question. A passing reference only can be made to it in this little volume, which is intended to furnish hints and aids to the better execution of the second part. For the benefit of the beginner who has to do with the location and construction a few definitions and hints relating to reconnoissance will be given before going on to the special problems arising in the work of the railroad engineer.

2. **The Reconnoissance** is a rapid, general survey of the *area* through which the proposed railroad must pass, made only with such instruments as can be easily carried, and which should enable the engineer to restrict the more accurate instrumental work that follows to one or two general lines. The time required for this part of the work will in general be only a small fraction of the time consumed in location, involving the service of very few men; yet there is no part of the work more rapidly and improperly done—not always because the engineer in charge underestimates its importance, but because he is not usually allowed sufficient time in which to study thoroughly the area under consideration.

Properly the reconnoissance includes the determination of the terminal points of the road, but the locating engineer is usually relieved from the necessity of selecting these points, and the question reduces to that of finding *the best available line which admits of being built, maintained, and operated at the least cost between two given points.*

The reconnoissance must be made over an *area*—not a line or lines. Even what seems the most unpromising portion should be carefully studied, for the engineer can never be satisfied he has selected the best route until he has convinced himself by careful study that all others are inferior. Too much haste on reconnoissance means either a poor line or a much greater expenditure of time and money on the preliminary. No amount of notes or topography can take the place of an intimate personal knowledge of the problems to be encountered, and hence the reconnoissance and preliminary survey should be made by the engineer who is to locate the road.

3. **The Instruments** needed will rarely be more than a pocket-compass, hand-level, aneroid barometer, field-glasses, and sometimes a pedometer or an odometer.

(*a*) **The Pocket-compass** is used to obtain the magnetic bearings of lines and the angles they make with each other.

(*b*) **The Hand-level** enables one to obtain differences of elevation between points not far apart.

(*c*) **The Aneroid Barometer** gives approximate heights of the mercury column, and serves to roughly determine the difference of elevation of given points. In addition to the scale giving readings in inches, it should have also a scale graduated to give readings in feet. If two aneroids, which have been previously compared, are read simultaneously, one at each of the points whose difference of elevation is desired, or if the same aneroid is read at each successively at a short interval of time, during which the atmospheric pressure has not sensibly altered, we may find the difference of elevation by the formula*

$$d = 60000(\log H - \log h)\left(1 + \frac{T + t - 60}{900}\right), \quad . \quad . \quad (1)$$

in which $d$ is the difference of altitude in feet, $H$ and $h$ the barometric readings in inches—the logarithms being of the common or Briggs kind, $T$ and $t$ the temperatures of the two stations in Fahrenheit degrees.

If the sum of the temperatures, $T + t$, is taken as 105°, formula (1) reduces to

$$d = 63000(\log H - \log h). \quad . \quad . \quad . \quad . \quad . \quad (1')$$

Example.—The reading of the barometer at the foot of a mountain is 28.8 inches, and at the top 26.7 inches. Required the height of the mountain.

By (1'). $d = 63000(\log 28.8 - \log 26.7) = 2071$ feet.

The effect of temperature on the metal of the instrument should be considered in the barometric formula when very precise work is to be done; but this correction, being small, may be neglected in the rough work of reconnoissance, particularly since the makers of the instrument construct it in such a way as to compensate, as closely as possible, for such changes of temperature.

(*d*) **The Pedometer** is an instrument which automatically counts the number of steps made by a person when the instrument is attached to his belt; then, knowing the average length of step, the distance passed over can be readily computed.

**The Odometer** registers the number of revolutions of a wheel to which it is attached, and the number of revolutions multiplied by the circumference of the wheel gives the space passed over.

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* See Plympton's Aneroid Barometer, p. 38, for formula (1).

**4. The Map.**—Before beginning the reconnoissance the engineer should provide himself with the best available map of the region to be traversed; if this is a topographic one, he can at once determine from it the lines that are likely to justify an examination; and even if it is only a sketch-map, he can get material assistance by observing the courses of the streams and remembering that their positions indicate the relative elevations of the portion of the region through which they flow. Thus the large streams follow the lines of least elevation, and the manner in which the lateral streams unite with the principal one indicates the general trend of the terrain. Two streams flowing nearly parallel approach or recede from each other according as the intervening land diminishes or increases in altitude. Two streams flowing away from each other on opposite sides of a divide, and having their source therein, approach each other closest at the point of least elevation, and indicate the position of a pass or the lowest point of the dividing ridge. The study of any good contour map covering sufficient area will illustrate the laws governing the courses followed by streams.

The elevations of a few correctly mapped points, when obtainable, from the map or otherwise, serve as a guide in tentatively fixing on the maximum gradient to be employed and the amount of development needed.

A skillful engineer will thus be enabled to project his lines with sufficient accuracy to enable him to select on the ground the most feasible route or routes for his preliminaries in the least possible time. He should guard against the conviction, however, that it is unnecessary for him to look elsewhere than along the projected routes; for the inaccuracies of the map, local peculiarities, the nature of the excavation and embankment, the number and cost of bridges and other mechanical structures,—all these may conspire to make the most promising map-line inferior to some other whose advantages have to be sought for on the ground.

**5.** Having tentatively decided on the limiting grades and curvature to be employed, the engineer goes carefully over the ground, examining the entire area that seems likely to afford passage, in order to determine whether a suitable line may be secured for the grades and curves previously assumed. With his pocket-compass he takes the bearings of lines, and by means of the hand-level and aneroid determines differences of elevation.

Distances are estimated by the eye, paced, and the count taken from the pedometer, or, if the country admits of the use of a vehicle, taken from the odometer readings. If a well-gaited saddle-horse is used, very good results may be gotten by timing him, or by the use of the pedometer if his stride is uniform.

But in all cases much dependence must be placed on the ability to estimate with the eye differences of elevation and distances. The ability to do this with even reasonable accuracy comes only from long practice and careful observation, even to the most gifted in this respect. New and unexpected conditions sometimes deceive even the most practiced eye, but under ordinary conditions almost any one can train his eye to estimate horizontal distances fairly well. Vertical heights are more deceptive, possibly because we have less practice in this line, and the mind seems naturally to exaggerate the vertical as compared with the horizontal; practice, however, will enable us to make allowance for the natural tendency to overestimate heights and slopes.

The ground should be gone over in both directions, for the appearance may be quite different when approached from different quarters. Ruling points, such as a pass in the mountains, the crossing of a large stream, or a town or city through which the road must be built, serve to reduce the problem to a number of special ones, each having its own solution.

In a mountainous region offering a limited number of possible routes, but heavy construction work, it may often happen that the location of a line is a much less difficult operation than in an open, rolling country offering a score of possible lines, between which the engineer making the reconnoissance must decide, selecting only those that in his judgment seem to justify an accurate instrumental survey.

The engineer must keep constantly in mind all the factors of the general problem of economic location and maintenance, and successful operation of trains. One line may cost more for construction and maintenance than another, but less for operation, or may invite less traffic. In all cases, however, the question of grades, curvature, length of line, earthwork, and mechanical structures are the controlling elements to be considered.

Having decided upon the route or routes over which to run preliminaries, these are marked on the map, and the engineering party organized and put in the field, with all the necessary instruments.

The reconnoissance should disclose which of the three following general classes the preliminary survey will probably come under:

(*a*) *Valley lines*, as will be the case for a railroad between two towns situated in the same valley, and on the same stream. The located line will follow the meanderings of the stream more or less closely and may sometimes be located entirely on one side of the stream, or it may cross and recross the stream. The hydraulic slope of the stream may not be uniform and the located line may have to be carried on the slopes of the hills some distance back from the stream in places. Valley locations generally present fewer difficulties than either of the others named below.

(*b*) *Cross-country lines* have always one or more summits which are controlling factors. The lowest available, practicable ones should be selected unless these should involve such an increase in length of line as to make a higher one preferable. If the line follows a stream up one side of a range of hills it will most probably be so located as to follow another down the opposite side, for low points in a divide indicate that the sources of streams on opposite sides of the range approach each other most closely at these points.

(*c*) *Mountain lines* usually require "development"—that is an increase in the length of line—in order to keep within the ruling grade. Sometimes this is accomplished by following up a lateral valley, on a continuous ascending grade if we are working toward the summit, and vice versa if we are receding from the summit, and introducing a sharp curve, crossing or rounding the lateral valley, then working back on the opposite side, still on the same character of gradient as was used on the first side of the lateral valley.

(*d*) *Switch-backs.*—Sometimes the natural ground slope is so steep that a "switch-back" must be used. This method permits the located line to be carried up the face of a steep slope. It involves slow and expensive operation of trains, however, because, after climbing as far as the topography permits, the train must be stopped, a switch thrown behind it, and the train backed up-grade as far as this branch of the switch-back extends, after which another switch is thrown in front of the train and forward movement made along another branch of the switch-back. This procedure is followed for as many branches as there are in the switch-back, each one requiring the train to come to a full stop.

(*e*) *Loops.*—Sometimes the located line must be made to double back and cross itself at a higher or a lower level, according as an ascent or a descent is being made, and not infrequently tunnels must be resorted to in making such loops.

# CHAPTER II.

## *PRELIMINARY SURVEYS.*

### ARTICLE 2. OBJECTS; THE FIELD CORPS; DUTIES OF THE CHIEF.

6. **The Objects** of the preliminary surveys are to secure all the data necessary to determine which one of the routes selected on reconnoissance is the most feasible, all things considered, and the approximate cost of construction. In rough country it will be economical to make two, or even three, surveys over the route selected for location before beginning to place the line in the position it is finally to occupy. The first of these is often omitted, and is called an "exploration-line"; it will frequently save the making of the more expensive "preliminary" over one or more of the routes.

7. **The Exploration-line** may be made with either transit or compass, and consists of a rapidly run line, made for the purpose of determining the maximum curvature and gradients with which to project the preliminary. It will not be necessary to make a detailed study of the region at this time, the distances and elevations, with such sketch topography as may be easily taken, being all that is needed. The magnetic bearing of lines is taken by the compassman, and the chainmen align each other with the flag set by the flagman. As the progress of the level party will be slower than that of the compass party, it will be economical to add an extra rodman, and sometimes a recorder. The compassman may sketch in the features adjacent to the line while waiting for his chainmen, who may be either in front of or behind the compass.

The stadia method of surveying—to be spoken of later—would seem to offer exceptional advantages for this work—only three or four men being needed in addition to the chief. With it, by setting the transit over alternate stations, very rapid progress may be made, and obstacles avoided with as much or greater ease than with the compass.

The exploration-line will more than pay for itself in showing what routes it will be unnecessary to make preliminaries over, and in indicating the most feasible one. It should be run over all the routes selected on reconnoissance.

8. **The Preliminary Survey** follows the exploration, or, when this is omitted, comes next after the reconnoissance. It may, with advantage, be made in two parts—first and second preliminary It is made with such instrumental accuracy as the nature of the case may demand, sufficient data being obtained to determine the best line on which to locate and the approximate cost of construction. The rapidity with which this work can be done will depend on the care with which the reconnoissance was made. The preliminary line should approximate, as closely as the eye can determine, to the position the located line should occupy, and forms the base on which the topographic work rests. In reasonably easy country, where exploration-lines have been run, one preliminary should suffice for each route, but in difficult regions it will be best to run a second preliminary. If portions of the route are easy, followed by difficult parts, it will often be sufficient to "back up" and re-run the difficult portion until a reasonably satisfactory line has been obtained.

9. **The Field Corps** consists of a chief of party, transitman, leveler, rodman, two chainmen, rear rodman or "back-flag," stakeman, and two or more axemen. If a topographic party is added, as it should be in any but the easiest country, there will be also a topographer with two or more assistants. A cook and teamster will be needed with the camp outfit.

The corps is usually divided into the following parties:

(*a*) THE TRANSIT PARTY.
(*b*) THE LEVEL PARTY.
(*c*) THE TOPOGRAPHIC PARTY.

10. **The Chief of Party** receives his orders from the chief engineer, or such other officer as may be in charge, directs the motions of the surveying corps, and is responsible for their conduct and progress. He provides accommodations and supplies, pays all expenses, taking receipts or vouchers for all outlays—in duplicate when required. In the less thickly populated sections he must provide tents, wagons, cook, and all necessary camping outfit and supplies. He must direct the field operations in person, keeping in advance of the transit, establish turning-points or hubs, and direct the transitman in the proper course. He should keep

a record—or direct the transitman and topographer to do so—of the character of earthwork likely to be encountered, the places where drains, culverts, bridges, cattle-guards, etc., are needed; the nature of material for embankment, piling, etc., adjacent to the line; the probable amount of clearing and grubbing, and all other features likely to affect the cost of construction. He should see that the names of property owners and residents along the line and the positions and bearings of property lines, when possible, are noted.

He should have authority to discharge assistants—except transitman, leveler, and topographer—whose services are unsatisfactory, and in many cases it will be best for him to have entire control, engaging or discharging any member of the corps as circumstances may require.

## ARTICLE 3. THE TRANSIT PARTY.

### *A. Duties of the Members.*

11. **The Transit Party** should consist of a transitman, head chainman, rear chainman, rear flagman, stakeman, and as many axemen as may be required—rarely less than two even for open country.

12. **The Transitman** cares for his instrument, keeping it in adjustment; directs the chainmen into line; notes the angle between successive tangents as read on plates; notes also the bearings of tangents, of highways, streams, and property lines (on location), with the plus at which the line crosses them. If there is no topographic party he must make sketches, on the right-hand page of note-book, of the surface features adjacent to the line; the red line down the middle of page represents the transit line, whether straight, broken, or curved, to which the sketches are adjusted. He must see that the axemen keep in line, in order that no unnecessary chopping may be done. Large trees need rarely be felled on preliminary, even when a given general course has to be followed, for small angles may be turned to avoid them, the deflections to right being made to approximately balance those to left.

When the chief of party is absent the transitman is ranking man, and will take temporary charge.

13. **The Head Chainman** carries a range-pole or "flag," and drags the chain, which he must see is straight and horizontal

when setting a point for a stake. He directs the stakeman where to drive his stake, calling out the number after the rear chainman has read and called out the number on his stake; he keeps the axemen in line by setting his flag and going ahead, directing them where to cut by keeping them in line with the flag and transit. The speed of the party is dependent on the rapidity and accuracy with which he can set his flag in position, by ranging with stakes already set between him and transit, and in seeing that the axemen make all their work count.

14. **The Rear Chainman** must be careful to hold his end of the chain in the proper place, and that it is kept straight and taut when the head chainman is setting a stake. He must give all pluses, note the number on each stake as he comes up to it, and see that the stakeman has marked it correctly; he must make a note of pluses for roads, fences, streams, etc., to be given to the transitman later on.

15. **The Stakeman** must keep himself supplied with stakes about 1½″ × 2″ × 24″, marking the number on them plainly, and driving them as directed by the head chainman.

If sawed stakes are not provided, he must cut the stakes and face them for the numbers. He must keep on hand a number of plugs or "hubs," to be driven flush with the ground and having the point where flag rested marked with a tack. About ten or twelve inches to the left of and facing the hub a guard stake is driven, on which is marked the station number, and which enables one to find the hub at any time.

16. **The Axemen** do all necessary clearing and chopping in order that the transit and level parties may have a clear sightway, and yet restrict the work of clearing to a minimum. One of them may be detailed to keep the stakeman supplied with stakes.

17. **The Rear Flagman** holds his flag on the last turning-point for the transitman to use in back-sighting.

18. **The Instruments** used by the party are the transit (or compass), one-hundred-foot-chain or tape, range-poles, and the necessary axes and hatchet for axemen and stakeman.

### *B. Transit Adjustments—The Vernier.*

19. For railroad work the transit is usually plain, but it is often convenient to have a clamp and tangent movement to tele-

scope, a vertical circle, a level on telescope, stadia wires, and a gradienter; the solar attachment will rarely be needed.

**20. To Adjust the Plate Levels.**—The axis of the instrument is set at right angles to the plates by the manufacturer, so that when the axis is made vertical the plates will be horizontal.

In making adjustments remember that *a complete reversal always doubles any existing error.*

Place the bubble-tube parallel to a diagonal pair of leveling-screws, and bring the bubble to the centre of its run. Revolve the instrument 180° on the vertical axis, and the level-tube will be parallel to the same pair of leveling-screws as before, but reversed. If the bubble has moved from its central position bring it *half*-way back by means of the capstan headed screws at the ends of the tube. Relevel and repeat until the bubble remains at the centre after reversal. Do the same for the other bubble. Both bubbles should remain at the centres of their tubes during a complete reversal.

**21. Parallax** is an apparent movement of the cross-wires with respect to the object sighted when the eye is moved from side to side of the eyepiece, and shows that the image does not fall in the plane of the cross-wires. In precise measurements it should be removed before making an observation with the telescope. To do this, first bring the cross-wires clearly into view when the object-glass is turned towards the sky, then, when sighting an object, note if there is any relative movement of cross-wires and image when the eye is moved from side to side at the eyepiece; if there is, refocus the object-glass until this movement disappears.

**22. To Adjust the Line of Collimation** is to make the line joining the intersection of cross-wires and optical center of objective describe a plane perpendicular to the horizontal axis of instrument.

FIRST METHOD.—Level the instrument and clamp the movements on vertical axis. Sight some well-defined object distant about the length of an average sight, and in the same horizontal plane as telescope. Reverse the telescope on its horizontal axis, and fix a point about as far from instrument as first point, and in the same horizontal plane. Revolve the instrument on its vertical axis and sight the first point; then reverse the telescope and note if line of sight cuts the second point. If not, loosen the capstan-headed screws holding cross-wire ring and move the vertical wire over *one fourth* the apparent error—since there were two reversals—remembering that the image of the cross-wires is inverted, while that of the object appears in its true position. Test by repetition.

SECOND METHOD.—If the limb graduations can be relied on they may be used in adjusting the vertical wire. With the instrument level sight a well-defined point, then revolve 180° by vernier-plate, reading both verniers; reverse telescope, and note if line of sight cuts the point. If not, correct *one half* the apparent error by moving diaphragm ; then test by repetition.

The manufacturers adjust the object-glass slide so that the objective travels in the telescope axis, and this adjustment is not liable to serious derangement. It is well, however, to sometimes test by adjusting the line of collimation for both near and distant objects. If not correct for both, move the ring which guides the rear end of object-glass slide until the adjustment is correct for both positions.

Next make the vertical wire vertical by noting if it coincides throughout its length with a plumb-line, or by observing if it deviates from a point, on which the intersection has been fixed, when the telescope is elevated or depressed. Any error is corrected by turning the ring after slightly loosening the screws holding it.

The horizontal wire should also be adjusted so that the intersection of the cross-wires will be in the axis of the telescope ; if the transit is to be used as a leveling instrument this adjustment is essential.

Drive a stake close to the instrument, and with the telescope clamped as nearly horizontal as can be conveniently done read a rod held on top of the stake ; about 300 feet distant, and in line with first stake and instrument, drive a second stake and read the rod on it. Revolve 180° on vertical axis, reverse the telescope and bring the horizontal wire to the former reading when the rod is held on first stake ; if the reading on the second stake is not the same as before, correct *one half* the apparent error by moving the cross-wire ring. Repeat as a test. The vertical wire should again be tested lest the movement of the ring may have caused it to change.

**23. To Adjust the Standards** is to make the plane described by the line of collimation vertical. Set up the transit about as far in front of some high building, or other tall object, as the highest point that can be sighted is above the base. Level the instrument and fix the intersection of the cross-wires on the highest point that can be easily sighted. Depress the telescope and fix a point near the base of the building at about the height of the telescope. Unclamp and revolve on the vertical axis until the telescope reversed cuts the lower point. Clamp the plates and raise the telescope until the cross-wires are at the height of the upper point. If they cut it the standards are in adjustment. If they do not, bring them *half-way* back by means of the adjustable screws at the top of one of the standards. Repeat as a test.

**24. To Adjust the Level on Telescope** is to make the bubble stand at the center of its run when the line of sight is horizontal. Bring the telescope as nearly horizontal as may be convenient, and take readings on the tops of two pegs in the same vertical plane with, and equidistant from, the instrument—say 300 feet. The difference of readings will equal the difference of elevation of the pegs; this difference may be obtained with the wye-level if preferred.

Move the instrument to a point beyond one of the pegs and in line with both. Set up as close to nearer peg as convenient, but not so close that the rod cannot be easily read. Bring the telescope as nearly horizontal as possible, and read on both pegs. If the difference of readings equals their difference of elevation the line of sight is horizontal, and the bubble may be brought to the center by means of the adjustable screws attaching the level-tube to the telescope. If this is not the case, we must set the telescope so the reading on second peg equals the reading on first peg plus the difference of elevation; then read again on first peg and proceed as before until the condition is satisfied. Or we may proceed as follows:

In Fig. 1 let the transit be at *O*, and *A* and *B* be the pegs. *AC* is a horizontal through *A*, so that *CB* is the difference of elevation

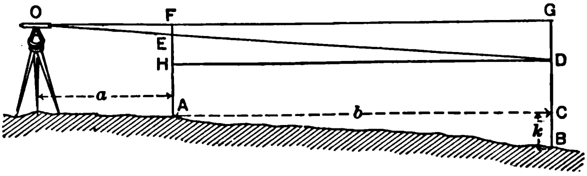

FIG. 1.

of *A* and *B*. Suppose line of sight to cut the rods at *E* and *D*, we must find *DG* so that the target may be set at the proper reading to make the line of sight horizontal. Let $OF = a$, $FG = b$, $EA = r$, $DB = r'$, $CB = k$. Draw $DH$ parallel to $CA$ and $OG$; then $EH = r + k - r'$.

From similar triangles

$$DG = EH\frac{a+b}{b} = (r + k - r')\left(\frac{a+b}{b}\right)$$

Set the target at a reading $GB = GD + r'$, sight to $G$, and the line of sight will be horizontal. Bring the bubble to the center of its run while the telescope is in this position, and the adjustment is complete.

If desired, a correction for the curvature of the earth and refraction may be introduced, but for short sights this is a useless refinement.

**25. The Vernier** is an auxiliary scale for measuring smaller divisions than those graduated on the limb. There are two classes, the direct-reading and the retrograde, according as the fractional parts of limb readings are taken on that side of the zero of vernier scale towards which the vernier has moved with respect to the limb, or the reverse. On the direct vernier a certain number of divisions on the vernier equals the same number of divisions on the limb, less one; on the retrograde there is one more division on limb than on vernier when the same space is covered by both.

**26. The Least Count** of a vernier is the smallest subdivision of limb graduation that can be read by it, and equals the difference of one space on limb and one on vernier.

Let $l$ = value of one space on limb;
$v$ = value of one space on vernier;
$n$ = number of spaces on vernier.

Then for the direct vernier

$$nv = (n - 1)l;$$

from which we get the least count,

$$l - v = \frac{l}{n}.$$

For the retrograde vernier

$$nv = (n + 1)l,$$

from which the least count is

$$v - l = \frac{l}{n},$$

the same result as found for the direct vernier.

So, to find the least count: *Divide the value of one limb space by the number of spaces on the vernier.*

For example: If the limb of a transit is divided to half-degrees and the number of spaces on the vernier is 30, the least count will be $\frac{1}{2}$ divided by 30, or $\frac{1}{60}$ of a degree—that is, 1 minute.

27. **To Read a Vernier,** take the number of the last division on limb back of the vernier zero, then look along the vernier until a line is found to coincide with a line on the limb; add the number of this vernier line, multiplied by the least count, to the scale reading, and the result will be the required reading.

## *C. Accessories.*

### (1°) *The Gradienter.*

28. **The Gradienter** consists of a tangent-screw having a micrometer-head, attached to one of the standards of the transit and capable of being clamped to the horizontal axis of the telescope. It is used—as its name indicates—in running grades, and it accurately measures a small vertical angle in terms of its tangent. The screw is so cut that one revolution moves the telescope through an angle whose tangent at one hundred feet from the instrument has a certain value, usually one foot. The graduated head is divided into 100 parts, so that one division corresponds to 0.01 ft. at 100 feet from instrument.

To run a given gradient, bring the telescope level and read the micrometer-head of screw; then turn the screw as many divisions as there are hundredths of a foot rise or fall in 100 feet, and with a target set at the height of the horizontal axis, points on the surface corresponding to the given grade can be found.

For example: To run a 0.75 per cent grade, move the micrometer milled head 75 graduations from the horizontal.

When used as a **Telemeter,** we may either measure the space on the rod moved over by the line of sight for a given number of revolutions of the screw, or we may note the number of revolutions required to move the line of sight over a certain space on rod. The second method is the more accurate, particularly for long sights.

### (2°) *The Stadia, or Telemeter.*

**29. The Stadia** is an instrument for determining the distance of a point from the observer by noting the space intercepted on a rod by a given visual angle, as determined by two auxiliary wires parallel to, and equidistant from, the horizontal wire of the transit telescope. When used with an ordinary leveling-rod the wires should be adjustable; if they are fixed (which for some reasons is preferable), the rod must be graduated to correspond. In addition to the distance of a point from the instrument, the difference of elevation is determined by observing the angle made by line of sight with the horizontal when the middle horizontal wire cuts a point on the rod as high above the ground as is the centre of the telescope.

The horizontal position of the point is determined from its magnetic bearing, or the azimuth of line of sight with reference to some fixed line, usually the north-south line.

**30. Line of Sight Horizontal.**—In Fig. 2 let $a$ and $b$ be the stadia wires, $AB$ the intercept on the rod. The secondary axes

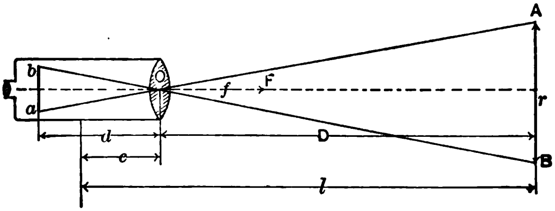

FIG. 2.

$aA$ and $bB$ pass through the optical center $O$. Let $h = ab$, $r = AB$, $d =$ distance of cross-wires from objective, $D =$ distance of rod from objective.

From similar triangles,

$$\frac{h}{d} = \frac{r}{D}.$$

From optics,

$$\frac{1}{d} + \frac{1}{D} = \frac{1}{f},$$

in which $f$ is the focal length of objective.

Eliminating $d$ from these two equations,

$$D = f + \frac{f}{h}r.$$

Let $c$ be the *mean* distance of objective from center of instrument. Adding this to $D$ gives, for the distance of the rod from the center of the instrument,

$$l = c + f + \frac{f}{h}r. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$\frac{f}{h}$ may be made constant, when (2) becomes

$$l = a + kr. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2')$$

**31. Line of Sight Inclined.**—When the line of sight is not level it is difficult to hold the rod perpendicular thereto; hence the rod is held vertical, the angle of inclination measured, and a correction applied. In Fig. 3

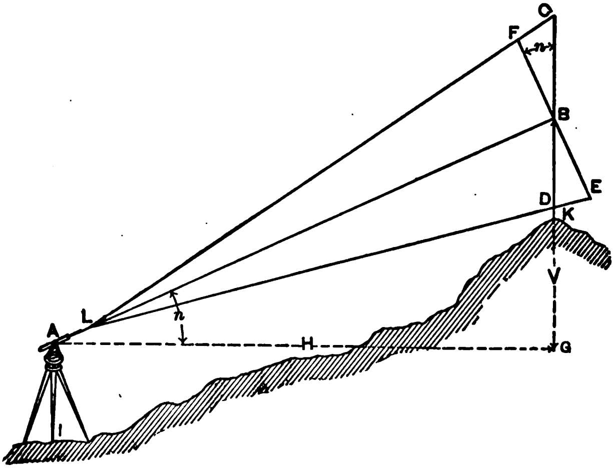

FIG. 3.

let $r = CD$ be the reading on rod held vertical;
$r' = FE$, the reading perpendicular to line of sight;
$H = AG$, the horizontal distance from $A$ to $B$;
$V = BG$, the difference of elevation between $A$ and $B$;
$n = BAG$, the angle of inclination of line of sight.

Assume angles $AFB$ and $AEB = 90°$, from which they rarely differ more than 15′ to 17′. Then, since $FBC = n$,

$$r' = r \cos n.$$

By (2'), $AB = a + kr'$.

Hence $AB = a + kr \cos n$.

From triangle $ABG$

$$H = AB \cos n$$

$$\therefore H = a \cos n + kr \cos^2 n. \quad \ldots \ldots \quad (3)$$

$$V = AB \sin n;$$

$$\therefore V = a \sin n + kr \sin n \cos n.$$

But $2 \sin n \cos n = \sin 2n$.

Hence $V = a \sin n + \frac{1}{2}kr \sin 2n. \quad \ldots \ldots \quad (4)$

**32. The Instrumental Constant** $a$ [$= c + f$ of (2)] may be found by measuring the distance from center of instrument to mean position of objective, which equals $c$; then focusing on a very distant object, preferably a star, and measuring from center of objective to plane of cross-wires, which equals $f$. The sum of these distances is $a$ in formulas (3) and (4).

If the stadia wires are fixed, $k$ may be found by measuring forward on level ground the distance $a$ from plumb-line, and from this point a further distance $b$; then note carefully the stadia reading $r$ when the telescope is level. Then, remembering (2)',

$$a + b = a + kr.$$

$$\therefore k = \frac{b}{r}, \text{ a constant ratio.}$$

If the stadia wires are adjustable, we may so adjust $k$ that any desired reading may be had for a given length of base. A convenient value of $k$ is 100, which corresponds to an intercept of 1 foot on the rod at 100 feet from a point $a$ feet in front of the instrument, 2 feet at 200 feet in front, etc.

**33. A Stadia Table** based on formulas (3) and (4) is published by the D. Van Nostrand Company in Winslow's *Stadia Surveying*, and can be used more rapidly than the formulas. Johnson's *Reduction Diagram*, by John Wiley & Sons, gives values of $H$ and $V$ graphically. Stadia slide-rules of various types are now on the market which admit of rapid determination of $V$ and of a correction to be applied to the apparent distance $AB$ to determine $H$.

### *D. Field-work.*

**34. Station Numbers** should begin with zero for the initial stake, and are marked on rear side of stake, from the top downward, the number of the preliminary, *A*, *B*, *C*, etc., being marked on the forward side. The marking should be with kiel, or crayon that will withstand the action of sun and rain. Stakes may be set every hundred feet or only at even stations, as preferred.

**35. Hubs, or Plugs**, are transit turning-points. and are short, flat-topped stakes driven into the ground flush with the surface. The flag is held on the top and carefully aligned, the position of the point being marked by a tack. A special tack with concave head offers a foothold for point of flag when used in backsighting.* About 10 inches to the left of and with numbered side facing the hub is driven a guard-stake to mark its position.

**36. Reference-points** are two or more hubs, with guard-stakes in each of two lines making a good intersection angle at the point whose position they serve to locate. They should be driven beyond reach of disturbance, and are used in replacing a dislocated hub.

These need rarely be used on preliminary.

**37. Alignment.**—It is not intended that the preliminary and location lines occupy exactly the same position; hence considerable latitude is allowable in the size and number of angles turned, care being taken, however, that the maximum curvature need not be exceeded on location. Large trees and other obstructions may be avoided by turning a small angle until the obstacle has been passed, then making a deflection in the opposite sense. Bearings of tangents are taken with the needle, to serve as a check on the angle read on the plates.

In easy country not requiring a topographic party large angles should not be turned, a succession of small ones with short intervening tangents being substituted in order to make the preliminary profile approximate more closely to the location profile. These short tangents may conveniently be the long chords of the curve that is to follow.

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* Such a tack is manufactured by the A. S. Aloe Co., St. Louis.

**38. The Transit Notes** may be kept in the form below, which shows both pages of the note-book. The notes run from the bottom up, the right-hand page being reserved for sketches; the red line up the middle of the page represents the transit line, whether straight or broken, to which the sketches must be adjusted.

| Sta. | Angle. | Calculated Course. | Magnetic Course. | Remarks and Sketches. |
|---|---|---|---|---|
| 68 | | | | |
| 67 ⊙ | 20° 0′ L. | N. 1° 48′ W. | N. 1° 45′ W. | ⊙ |
| 66 | | | | |
| 65 | | | | |
| 64 | | | | |
| 63 ⊙ | 6° 2′ R. | N. 18° 12′ E. | N. 18° 15′ E. | ⊙ |
| 62 | | | | |
| 61 | | | | |

**39. Stadia Methods for Preliminary Surveys.**—Preliminary lines are usually run with the transit, but the compass will answer nearly as well in most cases, besides admitting of more rapid work. The transit and stadia method might well be employed, and would effect considerable saving in the cost of preliminary surveys. For some reason railroad engineers have not regarded it with favor, though it is extensively employed in topographic surveying where the map is to be used for work that is often more precise than needed for railroad preliminaries.

Particularly is this method applicable to exploration lines. With the transit and stadia the entire surveying corps need not exceed five or six men, the instrument man acting as transitman, leveler, and topographer all in one. The only objection would seem to be in the amount of reduction the notes would need; however, with tables and slide-rule (see **33**) this work may be very rapidly done. For vertical angles of less than one degree the horizontal reduction can be neglected, and with side readings for topography the angle may be 5 or 10 degrees without necessitating the correction. Vertical heights are found by the slide-rule or by charts.

This method would really necessitate the making of a topographic map along a narrow strip of country, from which the profile could readily be taken. With a skilled observer and two to four rodmen the progress may be more rapid, and fully as good for the purpose intended as the more expensive method usually employed.

The transit need only be set at alternate stations (which may be any length within the reading limits of the wires), the bearings to other stations and points off the line being taken with the needle. The horizontal angle should also be read on the plates for points on stadia line, as a check on the bearings.

### *E. Obstacles in Tangent.*

**40.** Obstructions to vision and measurement in tangent may be avoided in a number of ways, a few of which are given in the following problems. Other methods of avoiding them will suggest themselves in special cases.

The same devices may be used on location, but it is more important to maintain a clear sightway then; so, when possible, we should remove the obstruction.

**41. To Pass an Obstacle by Means of Parallel Lines.**—In Fig. 4, $O$ is the obstruction, $AB$ the obstructed line. At $B$ set transit; turn 90° and measure $BF$ long enough to clear obstruction. Set transit at $F$, make $BFG = 90°$, and measure $FG$. Move to $G$ and backsight to $F$, making $FGC = 90°$. Measure $GC = FB$, and move to $C$, where the angle $GCD$ is made equal to 90°. $CD$ is the desired line, and $BC = FG$.

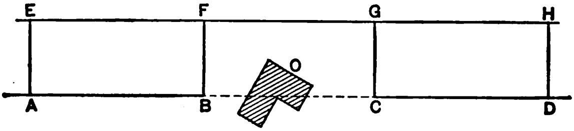


FIG. 4.

*Otherwise*, at $A$ and $B$ erect perpendiculars; take $BF = AE$; produce $EF$, and at $G$ and $H$, beyond $O$, erect perpendiculars making $GC = HD = FB$. $CD$ will be the desired line, and $BC = FG$.

**42. To Pass an Obstacle by Angular Deflections.**

GENERAL CASE. *Angle anything less than* 90°.

At $B$ (Fig. 5) on the obstructed line deflect an angle $a$ to one side and measure $BC$, taking $C$ so that after deflecting $2a$ to the other side $CD$ will clear the obstruction. Make $CD = BC$ and deflect an angle $a$ to the same side as at $B$; $DE$ will lie in $AB$ produced. Draw $CH$ perpendicular to $BD$; then

$$BD = BH + HD = 2BC \cos a. \quad . \quad . \quad . \quad . \quad (5)$$

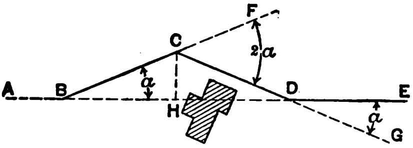


FIG. 5.

**EXAMPLE.**—Suppose $a = 14° 10'$, $BC = CD = 520$ ft.

$$BD = 2 \times 520 \times 0.96959 = 1008.37 \text{ feet.}$$

SPECIAL CASE. *Angle* 60 *degrees.*

In this case the triangle $BDF$ (Fig. 6) is equilateral and $BF = BD = DF$.

Should it be inconvenient to run to $D$ we may stop at $C$, having measured $BC$. At $C$ deflect 60° and measure $CE$; at $E$ again deflect 60° and make $EF = BC$. At $F$ a final deflection of 60° in the opposite sense will put the telescope in the desired line, $FG$, and

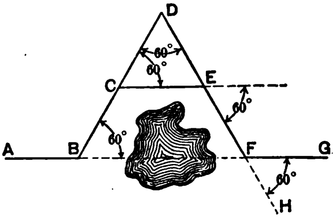


FIG. 6.

$$BF = BC + CE. \quad . \quad . \quad . \quad . \quad . \quad . \quad (5a)$$

**43. To Pass an Obstruction, such as a River, when the Preceding Methods are Inapplicable.**

FIRST CASE. *Point beyond obstruction visible.*

In Fig. 7 let $BC$ be required.

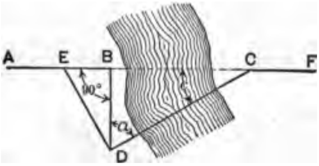


FIG. 7.

At $B$ erect and measure the perpendicular $BD$; set instrument at $D$ and measure angle $BDC = a$; then

$$BC = BD \tan a. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Or, if a trigonometric table is not at hand, make $CDE = 90°$ and fix the point $E$ where $DE$ intersects $AB$; measuring $EB$ there results, from similar triangles,

$$\frac{CB}{BD} = \frac{BD}{EB},$$

whence

$$CB = \frac{\overline{BD}^2}{EB}. \qquad \tag{6a}$$

*Otherwise*, if a right angle at $B$ is not convenient, measure angles $CBD = b$, $BDC = a$, and side $BD$. Then $c = 180° - (a + b)$.

From triangle $BDC$,

$$BC = BD\,\frac{\sin a}{\sin c}. \qquad \tag{6b}$$

EXAMPLE.—$a = 56°$, $b = 70°$, $BD = 400$ feet.

By (6*b*),

$$BC = 400\,\frac{\sin 56°}{\sin 54°} = 409.8 \text{ feet.}$$

SECOND CASE. *Point beyond obstruction invisible.*

At $B$ (Fig. 8) measure angle $b$ and line $BE$; move to $E$ and measure angle $y$, and set hubs on line $EC$ so the line $BC$ will pass between them. Angle $z = ECB = 180 - (b + y)$. Then from triangle $BEC$

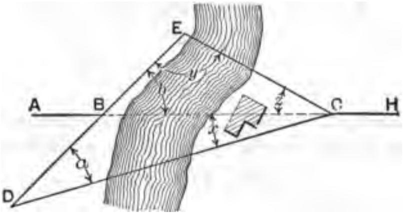


FIG. 8.

$$BC = BE\,\frac{\sin y}{\sin z}. \qquad \tag{7}$$

Produce $EB$ to $D$, where $DC$ will be sure to clear obstruction; measure $BD$.

From triangle $BDC$,

$$\frac{\tan \frac{1}{2}(a - x)}{\tan \frac{1}{2}(a + x)} = \frac{BC - BD}{BC + BD}.$$

But $a + x = b$, hence

$$\tan \tfrac{1}{2}(a - x) = \frac{BC - BD}{BC + BD} \cdot \tan \tfrac{1}{2}b. \qquad \tag{8}$$

The sum and difference of $a$ and $x$ are now known, so both may be readily found.

At $D$ set off the angle $a$ with the transit, and have the chainmen stretch a cord between the hubs set on line $EC$ at $C$. Now signal the flagman to move his rod along this cord until the vertical wire cuts it at $C$. Set a hub here and place the transit over it. Sight to $D$ or $E$, reverse telescope and deflect into $CH$.

If $b = 90°$ the problem is greatly simplified.

### ARTICLE 4.—THE LEVEL PARTY.

**44. The Level Party** consists generally of two members, the leveler and a rodman; sometimes an axeman is added to keep the rodman supplied with pegs for turning-points and in clearing the line of sight for the level. As the party follows the transit little or no clearing will be needed. The instruments used are a level, a rod, and a hand-axe or hatchet.

**45. The Leveler** makes all necessary observations with his instrument, keeping a neat, accurate record of readings and elevations; also the positions and elevations of benches and turning-points. He should work out elevations of stations while the rodman is going from one station to the next; he must see that the rodman gives him readings at points where the longitudinal slope changes suddenly, recording the plus. He must plot his profile at night, or at such times as the chief of party is likely to need it. The rodman's readings at turning-points should be checked.

**46. The Rodman** holds his rod at each station, calling out the number. If stakes are set only at even stations, he must hold his rod midway between stakes, the point being found by pacing the distance. Target-readings need only be taken at turning-points and benches, and the rodman should keep a record of these in his "peg-book," checking the calculations of leveler for heights of instrument and elevations of turning-points. At any marked surface change he will hold his rod, calling out the plus to leveler. He must assist the leveler in plotting up the notes.

### *A. Adjustments of the Level.*

**47. To Adjust the Line of Collimation** is to bring the intersection of the cross-wires into the optical axis of the telescope.

Set up and level the instrument, then bring the vertical wire into coincidence with a plumb-line or vertical edge of a building, at the mean length of sight, and note if the vertical wire is truly parallel thereto. If it is not, loosen the capstan-headed screws holding cross-wire ring and turn slightly so that the wire is parallel to the vertical line.

Loosen the wye-clips and bring the vertical wire into coincidence with the line and clamp the instrument. Rotate the telescope in the wyes 180° and note if the wire coincides with the line. If not, correct *one half* the error by loosening one and tightening the opposite, of the capstan-headed screws that hold the cross-wire ring in place, remembering that the image of the cross wires is inverted by the eyepiece.

Turn the telescope until the horizontal wire is parallel to the plumb-line or edge of building, and make the same test and correction. Repeat for both wires. The horizontal wire is the one on which the accuracy of leveling depends, but it is wise to have both adjusted. Their intersection should remain on a point during a complete rotation of the telescope in the wyes.

**48. To Adjust the Level-bubble** is to bring the axis of the level-tube into the same vertical plane with the line of collimation, and to make the bubble stand at the center when the line of sight is horizontal.

Since the axis of the telescope coincides with the line joining the center of the wye-rings (which requires these to be of the same size), it is sufficient to make the axis of the bubble parallel to this line.

(*a*) With the telescope over one diagonal pair of leveling-screws and the clips loosened, bring the bubble to the center of its run; then turn the telescope, in the wyes, a little to either side of the vertical plane through the telescope and note if the bubble remains at the center. If not, correct the error by means of the screw at end of the level-tube case arranged for lateral movement. Repeat until the tube may be rotated half an inch or more to either side of vertical without movement of the bubble. This adjustment is made merely to prevent error from failure to set level-tube vertically beneath telescope.

(*b*) With the wye-clips opened well out, again bring the bubble to the center of its run; remove the telescope from wyes and turn it end for end, then carefully replace it in the wyes. Should the bubble fail to remain at the center, bring it *half-way* back by raising the lower or depressing the higher end of tube at the points of attachment to telescope. Relevel and repeat as a test.

**49. To Adjust the Wyes** is to make the axis of the telescope perpendicular to the vertical axis. With the wye-clips closed place the telescope over one pair of leveling-screws and bring the bubble to the center of its run ; then turn the telescope half-way round on its vertical axis, so that its ends have changed places. If there is any error, correct by bringing the bubble *half-way* back to center by means of the screws connecting wyes with level-bar. Repeat until the bubble remains in the center during a complete revolution.

### *B. Theory of Leveling.*

**50.** When the level has been adjusted the line of collimation will describe a plane parallel to the horizontal plane tangent to the earth's surface at the point where the instrument is placed. A level surface, such as the surface of still water, will coincide with this plane only at the point of tangency, and will depart farther and farther therefrom as the point considered recedes from the instrument. For short sights this difference may be neglected in railroad work, as will presently be shown, but for long sights a correction must be applied.

The effect of curvature is to make objects appear lower than they really are, while the refraction of a beam of light, due to the greater density of the layers of air nearest the earth's surface, has a contrary effect. Experience shows the average error due to refraction to be about one seventh of that due to curvature.

**51. The Error due to Curvature** at any point is the deviation of a tangent line from true level, as the point recedes from the point of tangency.

Let $O$ be the center of the earth, $T$ the point of tangency, and $N$ the point where the error due to curvature is desired. Let the notation be as shown in Fig. 9. From the right triangle $OTP$, we have

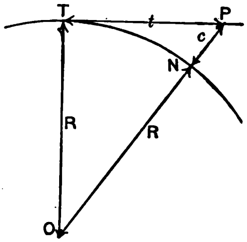


FIG. 9.

$$(R + c)^2 = R^2 + t^2.$$

From which

$$c = \frac{t^2}{2R + c}.$$

Now, since $c$ is always very small compared with $2R$, the quotient resulting from the division of $t^2$ by $2R$ will not differ sensibly from that obtained by dividing by $2R + c$. Therefore we write

$$c = \frac{t^2}{2R}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

For $t = 1$ mile, $R = 3963$ miles, $c =$ about 8 inches. Hence for any other distance in miles we have, for $c$,

$$c = 8 \times t^2 \text{ inches.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (9a)$$

The correction for refraction is about $\frac{1}{7}c$, hence we have, from (9),

$$C = c - \frac{1}{7}c = \frac{6}{7}c = \frac{3}{7}\frac{t^2}{R},$$

or, closely enough,

$$C = .85c. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (10)$$

Example.—What is the correction for a half-mile sight? For one eighth of a mile?

By (9$a$), $c = 8 \times (\frac{1}{2})^2 = 2''$ for first case,

and $c = 8 \times (\frac{1}{8})^2 = 0''.125$ for second case.

By (10) the final correction is

$c = 0.85 \times 2 = 1''.7$ for first case,

$c = 0.85 \times 0.125 = 0.106''$ for second case.

**52. The Difference of Elevation** between two points not so far apart but that a rod may be read on each from some intermediate point may be readily found from these rod-readings.

In Fig. 10 let the instrument be at $I$, $A$ and $B$ the points whose difference of elevation is desired. Let $r = AD$, $r' = BC$. Since the line of sight, $DC$, is horizontal, the difference of elevation will evidently be $r' - r$. When the distance from $I$ to $A$ equals that from $I$ to $B$ the errors due to curvature evidently balance.

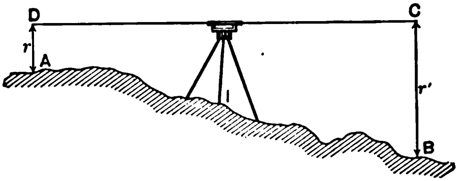


Fig. 10.

When the points are so situated that the rod cannot be read on both from one intermediate position of the instrument, an auxiliary point or points must be used and readings taken on these points in pairs. Thus in Fig. 11 suppose the difference of elevation of $A$ and $B$ required :

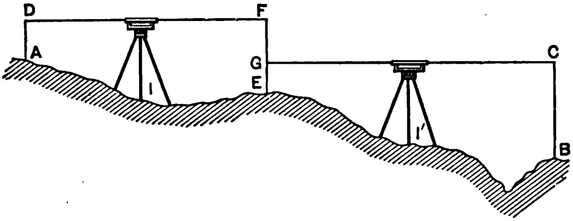


FIG. 11.

With the instrument at $I$ read on $A$ and some intermediate point $E$. Considering the backsights as plus and foresights as minus, the difference of elevation of $A$ and $E$ is $AD - FE$.

Again, with the instrument at $I'$ the difference of elevation of $E$ and $B$ is $GE - CB$. The sum of these differences equals the difference of elevation of $A$ and $B$, and may be written $(AD + GE) - (EF + CB)$, or, in general, *the sum of the backsights less the sum of the foresights equals the difference of elevation.*

### *C. Field-work.*

**53. A Datum** is a level surface so taken that it shall lie below the lowest point likely to be reached by the profile, to which the surface elevations are referred. It is often spoken of as the datum line or datum-plane, and is the zero of elevations.

**54. A Bench-mark** is a permanent mark, such as a copper or other bolt let into the top of a solidly fixed stone, whose height above the datum is known; it may be simply a mark on a stone, or a tack driven into the projecting root of a tree, upon which the rod may be read. In any case it must be so situated that it cannot change its elevation nor is likely to be disturbed within the time for which it is intended to be used as a standard of reference.

The elevation should be marked on some object adjacent to the bench, with the letters B. M. indicating the nature of the point.

**55. The Field-work** consists in finding the elevation of a number of points on the line established by transit party sufficient to give, when plotted, a fairly correct outline of the surface as seen in profile.

A bench-mark is taken at the beginning of the line, and its distance above mean sea-level or other datum is known or assumed. The level is set with one pair of leveling screws in the line to be run (in order that any change in the position of the bubble may be easily corrected), and the rod is read on the bench. This reading plus the elevation of bench gives the height of instrument (*H. I.*) above the datum.

Readings are taken at every hundred feet along the line, or oftener if the surface changes greatly, until a point is reached beyond which it is desired to move the level. A peg is driven firmly into the ground and the rod read on this; the height of instrument less the rod reading will give its elevation, as it will for the intermediate points. This point is a temporary bench and is called a **turning-point.** It should be marked by a guard-stake if it is desired to use it again. The instrument is now carried beyond the turning-point, set up, and the whole process repeated. Benches and turning points should be read to hundredths or thousandths of a foot, intermediate points to tenths. Turning-points are marked ⊙ or T. P. in the notes, and their positions, as also the bench-marks, noted by both leveler and rodman in their note-books.

**56. The Level Notes** may be kept in any convenient form that is easily understood. The following is used more extensively, perhaps, than any other:

| Sta. | B. S. | H. I. | F. S. | Elev. | Remarks. |
|---|---|---|---|---|---|
| B. M. | 5.613 | 205.613 | .... | 200.0 | B. M. on root of L. O. tree 60′ to right of line. |
| 0 | .... | .... | 2.3 | 203.3 | |
| 1 | .... | .... | 0.8 | 204.8 | |
| 2 | .... | .... | 5.7 | 199.9 | |
| 3 | .... | .... | 7.8 | 197.8 | |
| 4 | .... | .... | 9.9 | 195.7 | |
| ⊙ | 1.120 | 196.310 | 10.423 | 195.190 | On peg at 4 + 30′ – 20′ to left of line, by small P. O. tree. |
| 5 | .... | .... | 6.3 | 190.0 | |
| 6 | .... | .... | 4.5 | 191.8 | |

Here the elevation of the datum was taken 200.00 feet below the first bench-mark. The instrument was set up near Station 2, and a reading of 5.613 taken on the bench; this was written in the *B. S.* column, and when added to the elevation of the bench gives the height of instrument, 205.613. A reading of 2.3 was taken on Sta. 0, recorded in the *F.S.* column, and when subtracted from the *H.I.* yields an elevation of 203.3. The elevations of other points were determined in the same way. A little beyond Station 4 the rodman drove a peg and held the rod on it, yielding a reading of 10.423 and an elevation of 195.190. The instrument was then moved to a point near Station 7 and a reading of 1.120 taken on the peg; this added to 195.190 made the new *H. I.* 196.310, and the process continued with this *H. I.*

In most cases it will be sufficient to read benches and turning-points to hundredths and intermediate points to tenths.

It will be seen from the notes that any error in a turning-point causes the same error in all succeeding points. To guard against this the rodman is required to keep a "peg-book," in which the heights of instrument and elevations of turning-points are recorded, and which must check with the leveler's record.

**57.** Wind and sunshine affect the accuracy of the work with the level, as is also the case with the transit. For very great accuracy a calm, cloudy day is the best, but the railroad engineer cannot always choose the best times for his work, and must take such precautions as may be possible while he exercises the greatest care to prevent and detect errors. The adjustments should be tested at least once a week, even when the greatest care has been taken, for unequal expansion and other causes may conspire to cause them to change.

By making foresights and backsights to turning-points about equal the error due to curvature will be eliminated; the readings of rodman at these points should also be checked. The rodman should hold his rod vertical, which is sometimes accomplished by means of a level attached to rod; or the leveler can tell by his vertical wire when the rod is in the same vertical plane with the instrument, and by causing the rodman to wave his rod back and forth slowly, after clamping the target, he can tell if the horizontal wire just bisects the target at its highest position.

**58. The Rod** should be graduated to feet and tenths, reading by target at turning-points and benches; intermediate readings are made by the leveler at his instrument. Strength and durability are essential qualities. The Philadelphia rod seems to answer the purpose as well as any other now manufactured; the Troy rod may be used in the same manner as the Philadelphia rod, but is lighter and less able to stand rough usage.

## ARTICLE 5. THE TOPOGRAPHIC PARTY.

**59. The Topographic Party** follows the level and secures all the data necessary for making an accurate contour-map of a strip of country extending as far each side of the preliminary as may be needed for the intelligent projection of the location-line. This distance may vary from 50 to 300 or 400 feet, its width depending on the difficulties to be encountered and the degree of precision with which the preliminary approximates to the final location-line. The lateral slope of surface is obtained at the stations of preliminary by means of the hand-level and tape, by the slope-level or clinometer, by cross section rods, or by the transit and stadia. Strictly speaking the topography includes all the surface features, but for railroad work the surface elevations, streams, and nature of surface are the most important; it may be necessary to note the positions of roads, buildings, etc., and should always be done when practicable without undue loss of time. A pocket-compass will be of use in observing the bearings of lines.

**60.** There are two methods of recording the data obtained; one by means of notes and sketches in a book, the other by drawing the contours directly on the field-sheet as the data are obtained. Station elevations can be taken direct from the leveler's notes, and constitute the base on which the contour elevations rest.

Suppose the hand-level to be used and the notes kept in a book, to be afterwards transferred to the map. Starting with the known center elevation, the topographer notes the height of his eye above the ground and calculates the height of center above or below the next contour; from this the reading of the rod when held on this contour is found, being the height of station above contour plus the height of eye. He directs the slopeman in or out on a line at right angles to preliminary until this reading is given by the hand-level; the distance out is then measured and recorded, just as in setting slope-stakes, and the slopeman directed into position on the next contour, in the same manner.

Thus if 5-foot contour-intervals are employed, and the station elevation is 321.6 feet and the height of eye 5.3 feet, we shall have for the reading at the 320-foot contour 5.3 + (321.6 – 320) = 6.9. Motion the slopeman down the slope until his rod reads 6.9 and measure the distance out, suppose 21 feet. The 315-foot contour will be 5 feet lower, giving a reading of 11.9, which may be found in like manner at, say, 80 feet out. As the rod reads only to about 12 feet the topographer must move out to this last point, and with the reading 5.3 + 5 = 10.3 find the 310-foot contour in the same way. On the up-hill side the 325-foot contour will be found with a reading of 5.3 – (325 – 321.6) = 1.9 feet, and other contours in like manner.

The notes may be written thus

| Sta. | Left. | Center Elev. | Right. |
|---|---|---|---|
| 824 | $\frac{305}{193}, \frac{310}{125}, \frac{315}{80}, \frac{320}{21}$ | 321.6 | $\frac{325}{27}, \frac{330}{56}, \frac{335}{80}, \frac{340}{112}$ |

The number above the line is the contour elevation, the number below its distance out from center.

If preferred the elevation can be taken at regular distances out and recorded as above; the position of the contour will then be found by interpolation when mapping the work.

**61.** If the topography is to be plotted in as the work progresses the topographer must have a light drawing-board with a pocket and flap on back for holding the sheets on which the transit-line has been plotted the night before; the station elevations are marked on the line and the contour positions spotted in as obtained by slopemen, after which the contours are sketched in. Points where contours cross transit-line are found in the same manner as side points. The size of the sheets will depend on the taste of topographer and size of drawing-board; 17×24 to 19×28 inches are good sizes.

The topographer will soon learn to guess at the position his contours will occupy at the next station ahead, and will sketch them in lightly, to be erased and corrected when necessary. It is often sufficient to take lateral readings at every second or third station.

**62.** If the **Slope-level** is used, the inclination of the surface is obtained; then by the use of a scale constructed to show the horizontal distance apart of contours, for the given contour-interval, for slopes varying from 1° to 20°, the position of contours can at once be spotted on the map. Wellington recommends the use of the altazimuth as permitting the employment of either method at will—the altazimuth being merely a hand-level with a clinometer attached.

63. **Cross-section Rods** are measuring-rods 10 or 12 feet long carrying a level-bubble. By placing one end at the center, bringing the rod horizontal, and noting the height of the end of rod on the down-hill side, the slope may readily be obtained and the contours worked in as before. For very rough, broken ground this method may be preferable to either of the others.

64. If the **Transit and Stadia** are employed, very elaborate topography may be taken with very little field-work, but the observations require considerable reduction. With a suitable topographic protractor and the slide-rule mentioned in 33, the large number of points that may be obtained from each setting of the transit may be readily plotted and their elevations marked on the plot, after which the contour-lines can be worked in, and other features mapped. For small vertical angles no horizontal reduction is needed.

While not generally favored by railroad engineers in the past, this method is probably the most rapid and economical of any so far employed in topographic work.

## ARTICLE 6. PRELIMINARY ESTIMATES.

65. After completing the field-work of the preliminary survey the party is usually disbanded, only the transitman, leveler, and topographer being retained to assist the chief of party to complete the map, profile, and estimate of cost.

66. **The Map** may be drawn to any suitable scale, but less than 400 feet to the inch is not to be recommended where it must be used in projecting location. The transit-line is laid down first and the topography worked in afterwards from the field-map or topographer's notes. If it is wanted on a continuous sheet, the transit-line must first be drawn on a succession of small sheets, which are added as the plotting progresses, a new sheet being slipped under the edge of the preceding and tacked down when

required. The overlapping edge is marked by a number of short lines extending over onto the sheet beneath, to enable one to replace in the proper position. When the line has been plotted the sheets are pasted together and the whole shifted so as to bring the transit-line over the continuous sheet. Angular points are then pricked through and the line drawn on the continuous sheet. Ordinarily it will answer to have the map drawn on a succession of small sheets, to be joined together as required.

The plotting had best be done by bearings, though it may be done from the deflection angles, provided care is used to check frequently by bearings. Otherwise an error in one angle will throw all the remaining portion of the line out of position.

If more than one preliminary was run, they should all be shown on the same sheet whenever possible.

**66a. Land Line Ties** should be made on both preliminary and location surveys at the time the field work is being done, for the reasons given in the following paragraphs supplied by Mr. C. M. Kurtz, author of *Modern Location of Standard Turnouts*:

"A matter of primary importance in running a location line is to properly co-ordinate it, wherever possible, to all property lines and corners and also state, county, town and section lines. In those portions of the United States and Canada where the land has been surveyed into townships, sections, etc., it is very necessary to tie the surveyed railroad line to the lines and corners of the public land surveys.

"This is a very simple matter in some comparatively flat and long-settled portions of the United States, where the centers of the county roads have been established on section lines, and the section corners are located at county road intersections. In such locations the survey station and angles at which the location line crosses the land lines can be observed by the transit party as it goes forward along the line, and the distances to the corners can be measured by two extra chainmen. West of the Rocky Mountains, however, these conditions seldom occur, for section lines are more often than otherwise *not* defined by either fences or roads, and section corners will often prove to be lost or obliterated. In this case it becomes a very important function of the topographic party to hunt up all corners which can be found in the vicinity of the located line, and to make the usual tie by survey station, angle of crossing and distance to the corner. It may be necessary to run a random section line between corners, intersecting it with the railroad line, and then from such survey data obtain the tie to the true line by computation.

"If time or conditions will not permit such a survey to be made, it may suffice to make simple polar co-ordinate ties, either by a direct or traverse line, according to conditions, to the corners from some convenient point on the located line. In general, however, it will be time and money well spent to have land line ties made, wherever possible, from station intersection of section line, angle and distance to nearest corner, and to have these ties made before right of way purchase or beginning of construction.

"Where the new railroad line traverses government owned land it is imperative that ties to the public land survey lines and corners be recorded on all maps made for filing purposes.

"Land line ties enable the location party draftsman to correctly map the sections, townships, etc., as the location line is plotted, and later to show proper ownership of the various parcels of land crossed by the railroad. This is vitally important in making right of way purchases. The ownership of unoccupied but privately owned land is best determined from records in the county assessor's office."

**67. The Profile** is drawn on specially engraved paper, preferably a thin and translucent paper bearing orange-colored lines so as to admit of blue printing, or, better still, on profile tracing linen, also engraved with orange-colored lines. The scale adopted will depend upon the paper used, but in nearly all cases the vertical scale is greatly exaggerated as compared with the horizontal. When distances and elevations are measured in feet both Plate "A" and Plate "B" are in common use. Plate "A" has vertical lines spaced one-fourth inch apart, every tenth line being heavier than the others. It has horizontal lines spaced one-twentieth of an inch apart, every fifth line being heavier than the intermediate ones, and every fiftieth line heavier still. For the normal scale of the paper 400 feet horizontal equal 1 inch and 20 feet vertical equal 1 inch. This makes the exaggeration of vertical to horizontal 20 to 1. This plate is more generally used than is Plate "B," especially where rock work is expected. Plate "B" has the same general plan of engraving as Plate "A" except that the spacings are 4×30 to the inch, as against 4×20 to the inch for Plate "A." Another form of spacing is 5×25 to the inch, known as Plate "C," which, however, is less frequently used. There is also a metric paper, graduated to millimeters both ways, with every tenth line heavier than the others, which may be used for a variety of purposes. It is especially adapted for use when measurements are made in the metric system.

68. **Preliminary Estimates** of quantities are made by assuming a grade-line and drawing it on the profile; then the cuts and fills are taken from the profile, and the corresponding quantities obtained from Table XIX for the base the road is intended to have when completed. The nature of the work, whether ordinary earth or rock, can, of course, be only roughly estimated.

Bridging is estimated from the profile where piling or framed bents may be used, but where piers and long spans are needed special surveys with soundings are required. Culverts, drains, cattle guards, cross-ties, and rails for main line and sidings, switch stands, buildings, right of way, clearing, and other factors entering into the question of cost must all be considered and allowed for in making up the estimate.

Engineering expenses and unforeseen outlays that are sure to arise should have a liberal allowance.

69. **The Report** of the chief of party should set forth the advantages and probable cost of each of the several lines run when there is more than one. On this report frequently depends whether or not the line is to be located, and it should be clear and exhaustive, though plainly and concisely worded. The map and profile form an integral part of the report and show from what data the estimates were derived.

# CHAPTER III.

## *LOCATION.*

### ARTICLE 7. PROJECTING LOCATION.

**70.** After the preliminary has been mapped and the topography worked in, the engineer proceeds to make a paper location for his guidance in the field. The solution of the varied and complex problems that confront him are more or less interdependent. The guiding principle, applicable to all departments of engineering, that *the best structure is that which for the least cost best answers the purpose for which it was intended*, should control, even though the resulting structure be inferior, in point of scientific design, to some other. The best road as regards construction and grades may be a failure because of excessive first cost, while the cheapest construction will entail such heavy operating expenses that it may be equally unprofitable. The alignment must be as free from curves as possible, while heavy grades are at the same time excluded; these two requirements conflict and must be as well adjusted as possible. The amount of earthwork, of bridging and other structures must be kept down to the lowest limits.

**71.** Starting at the summit of the most difficult portion of the route, assume a starting-point and elevation; with the dividers set at such a distance to the scale of the map as will give a fall of one contour-space—or half space—for the assumed grade, step down the slope in such a way that the dividers fall each time on the next lower contour, or half-space, according to the fall assumed in setting dividers. If curve compensation is allowed, the dividers must be reset for each curve, for the same fall, since the grade will be slackened on curves. The points at which the dividers fall are lightly spotted on the map and connected by a **grade contour**, which represents the surface-line having the required gradient. This line will be too broken to be used as a location-line, so we have then to draw on the map a succession of curves and tangents that will approximate sufficiently close to it, at the same time that a proper balance is maintained between earthwork and curvature.

Having lightly plotted the proposed line, the elevations are transferred to profile-paper, thus giving a profile of the line.

With a fine thread stretched along the profile, to represent the grade-line, adjust the cuts and fills to suit the nature of the work. In general, fills are cheaper than cuts both in construction and maintenance; and especially is this true where a shallow surface layer of earth is underlaid by rock. It may happen that the material from excavation must be used in embankment, when the cuts and fills must be made to balance by shifting the grade-line until this appears to be the case on the profile.

At the stream crossings the grade-line must be kept safely above high-water mark, so that sufficient waterway is provided, and allowance made therefor.

After locating the most difficult portions pass on to the easier work, returning later on to study the effect this will have on the part first located. It may be necessary to go over the projection several times before you can be reasonably sure that the best location has been projected; even then the study of the line in the field will cause many of the details to be altered, sometimes materially.

Long grades are to be preferred to short ones, but questions of economy may necessitate the latter in order to lighten work; care must be taken that the grades are not so badly "chopped" that they interfere with the easy riding of the train.

In projecting the line it will generally be best to strike the curves first and draw the tangents afterwards, though it sometimes happens that long tangents will control the curves; when this is the case the tangents are drawn to intersection and the curves afterwards put in.

When transition-curves are employed, a slight offset should be made at the beginning and end of curves to allow for their insertion in the field. These offsets will be so small that it is useless to attempt to show them to scale.

**72. A Curve-protractor** will be of material assistance in finding the degree of curve required to unite two tangents that have been laid down on the map. It consists of a transparent, semicircular protractor having a series of curves from 30′ up to 8° plainly cut upon it. The curves are on both sides, those on the reverse side having their concavities turned in an opposite sense from those on the face. The scale is usually 400 feet to the inch, and in any case the map and protractor must be drawn to the same scale. Sometimes a set of cardboard or hard-rubber curves are used, but they are inferior to the curve-protractor. To use it, simply prolong tangents to intersection and then place the protractor so that the curve admitting of the best grade is tangent to the two straight lines. Mark the points of tangency, which will be the beginning and end of curve. When the curve is required to pass through a given point the proper curve may be immediately found by trial, whereas the calculations would require some little time.

Reversed curves should never be allowed on main lines. Sufficient tangent should be interposed to allow space for easing off the superelevation of outside rails, or for the insertion of transition-curves when these are to be employed.

73. **The Field Corps** is substantially that required on the preliminary survey, and the methods of work pretty much the same, except that curves must now be run in, and this necessitates more clearing. If first and second location-lines are to be run (and it is real economy to run both), it will not be necessary to have the stationing continuous on the first, so the pluses arising from "backing up" need only be noted and eliminated when the final location-line is run. If transition-curves are to be inserted, they need not be run the first time, the proper offset being made at the *P.T.* or *P.C* of the circular curves, which latter are to be run.

On the final location-line the stationing must be continuous, beginning with zero. The stakes are marked as on the preliminary survey, and all hubs that are likely to be used again must be referenced in, the reference-hubs being set well out of the way of disturbance by the plow or scraper.

The leveler should make bench-marks every 1000 or 2000 feet, to be used in running check-levels and in giving grades later on.

From the paper location the notes should be made up in the office, to serve as a guide in the field; however, no attempt should be made to adhere rigidly to them, since slight errors in the mapping will affect the projected line, while in the field the line may be shifted here and there so as to fit the ground more snugly and accord more closely with what the nature of the earthwork demands.

The highest skill of the engineer is required to secure the best location-line, and he should have all the time he needs. Undue haste on location—as on reconnoissance and preliminary—is almost sure to result in increased cost of construction.

## ARTICLE 8. SIMPLE CURVES.

### *A. Definitions and Formulas.*

**74. The Circular Curves** that are usually employed to unite straight reaches of the railroad may be simple, compound, or reversed. The use of reversed curves should, however, be limited to turnouts and cross-overs.

*a.* **A Simple Curve** is the arc of a circle.

*b.* **A Compound Curve** consists of two simple curves, of different radii, both on the same side of a common tangent.

*c.* **A Reversed Curve** is made up of two curves of contrary flexure having the same or different radii, and a common tangent.

*d.* **The Point of Curve** (*P. C.*) is the end of tangent and beginning of curve, as at *A*, Fig. 12.

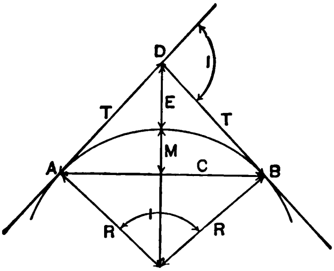


FIG. 12.

*e.* **The Point of Tangent** (*P. T.*) is the end of curve and beginning of tangent, as at *B* of Fig. 12.

*f.* **The Point of Intersection** (*P. I.*) is the point where the tangent at the *P.C.* and *P.T.* intersect when produced. (*D* of Fig. 12.)

*g.* **The Intersection Angle** (*I*) is the angle at the *P.I.* between the tangents meeting there and equals the angle at the center.

*h.* **The Tangent Distance** (*T*) is the length of the produced tangent measured from the *P. C.* or *P. T.* to the *P.I.* The term *tangent* is applied to any straight portion of the line, but the letter *T* will be used to designate the produced portion only.

*i.* **The Mid-ordinate** (*M*) is the portion of the radius intercepted between the arc and chord when it cuts the chord at its middle point.

*j.* **The External** (*E*) is the part of the radius produced to the *P.I.*, intercepted between curve and the *P.I.*

*k.* **The Long Chord** (*L.C.*) is the chord joining the *P.C.* and *P.T.* Frequently the term is applied to any chord longer than the unit chord.

*l.* **The Radius** will be denoted by *R.*

*m.* **The Point of Compound Curve** (*P.C.C.*) is the point of common tangency of the two branches of a compound curve. (See Fig. 13.)

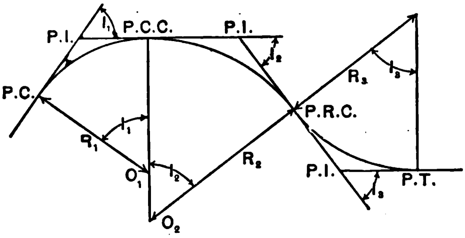


FIG. 13.

*n.* **The Point of Reversed Curve** (*P.R.C.*) is the point of common tangency of the two branches of a reversed curve.

*o.* **The Degree of Curve** (*D*) is the angle at the center subtended by the unit chord. In the United States this chord is 100 feet, in England 66 feet, and where the metric system is employed it is taken at 20 meters. Any convenient chord length may be taken, but for uniformity American engineers have adopted the chord of 100 feet, and unless otherwise stated it is always so understood when we speak of the degree of curve.

Half the degree of curve is called the **deflection-angle**, since it is the angle to be deflected from the tangent to the chord.

If there were any practical method of measuring *around the curve* instead of along the chord, an accurate and convenient ratio for expressing the radius in terms of the degree would be had. Thus if *D* is the angle at the center subtended by the *arc* of unit length, we have, where *a* is this unit arc,

$$2\pi R = a \cdot \frac{360}{D}.$$

Hence

$$R = \frac{a}{2\pi} \cdot \frac{360}{D}. \qquad (11)$$

When *a* equals 100 ft. this becomes

$$R = \frac{100}{2\pi} \cdot \frac{360}{D} = \frac{5729.65}{D}. \qquad (11')$$

*R* varies inversely as *D*, so that knowing the radius for a 1° curve, we should have only to divide this by *D* to get the radius for a *D*° curve.

Since the chord is employed instead of the arc, we determine *R* by means of the following problem

**75. Given the Chord *C*, and Degree of Curve *D*, to Find the Radius *R*.**

In Fig. 14, *AB* is the chord *C*, *OE* a perpendicular from the center upon *AB*

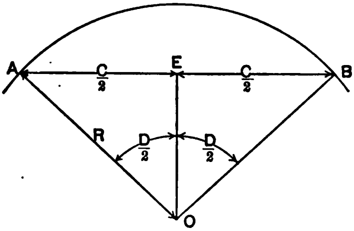


FIG. 14.

From the right triangle *AEO* we have

$$R \sin \tfrac{1}{2}D = \tfrac{1}{2}C.$$

Whence

$$R = \frac{\tfrac{1}{2}C}{\sin \tfrac{1}{2}D} = \tfrac{1}{2}C \operatorname{cosec} \tfrac{1}{2}D. \quad . \quad . \quad (12)$$

When *C* is 100 ft.,

$$R = \frac{50}{\sin \tfrac{1}{2}D} = 50 \operatorname{cosec} \tfrac{1}{2}D. \quad . \quad . \quad (12')$$

Comparing results given by formula (12′) with those given by (11′), we have for a few curves:

| Degree of Curve. | *R* by (12′). | *R* by (11′). | Difference. |
|---|---|---|---|
| 1............ | 5729.65 | 5729.58 | 0.07 |
| 2............ | 2864.93 | 2864.79 | 0.14 |
| 3............ | 1910.08 | 1909.86 | 0.22 |
| 5............ | 1146.28 | 1145.92 | 0.36 |
| 7............ | 819.02 | 818.51 | 0.51 |
| 10............ | 573.69 | 572.96 | 0.73 |
| 14............ | 410.28 | 409.26 | 1.02 |
| 20............ | 287.94 | 286.48 | 1.46 |

The difference is seen to be about one half a foot for a 7° curve, one foot for a 14° curve, and one and one-half feet for a 20° curve.

Up to a 7° curve the difference is inconsiderable, and we may stake out curves with 100-foot chords. From 7 to 14 degrees 50-foot chords may be used. Therefore

$$R = \frac{25}{\sin \frac{1}{4}D} = 25 \operatorname{cosec} \tfrac{1}{4}D. \quad . \quad . \quad . \quad . \quad . \qquad (12'a)$$

For curves from 14° to 28° we should use 25-foot chords, for which

$$R = \frac{12.5}{\sin \frac{1}{8}D} = 12.5 \operatorname{cosec} \tfrac{1}{8}D. \quad . \quad . \quad . \quad . \qquad (12'b)$$

Above 28° shorter chords—say 10 feet—should be used, if the curve cannot be struck from the center. In this case

$$R = \frac{5}{\sin \frac{1}{20}D} = 5 \operatorname{cosec} \tfrac{1}{20}D. \quad . \quad . \quad . \quad . \qquad (12'c)$$

Table I of radii was computed by formulas (12'), (12'a), and (12'b).

In practice it is customary to take the radius of a 1° curve as 5730 feet and to assume the radii to vary inversely as the degree; thus for a 4° curve the radius would be $R = \frac{5730}{4} = 1432.5$ feet, while by Table I it is 1432.69 feet—a difference of only .19 foot; for a 12° curve $R = \frac{5730}{12} = 477.5$ feet, while by Table I it is 477.68 feet. The effect of taking 5730 instead of 5729.65 for the radius of a 1° curve is to reduce the error resulting from the assumption that $R$ equals 5730 divided by the degree of curve.

**75a. The Radii of Metric Curves** are based on the use of 20 meter chords, equivalent to 65.6174 feet, since one meter equals 3.280869 feet. Successive stakes are given even numbers, as 224, 226, 228, etc., in order that any given number, multiplied by ten, will give the length of the line in meters from the beginning to the station in question. If numbered continuously the station number must be multiplied by 20 in order to obtain the length in meters from the origin.

The French designate the degree of curve by the angle between the tangent and the chord instead of by the angle at the center, or by half of what we call the degree of curve. Therefore, a curve having a central angle of 4°, for one chord length, would be called a 2° curve.

If $R_m$ is the radius of a metric curve, $d_m$ its degree, as defined above, then

$$R_m = 10 \div \sin d_m = 10 \operatorname{cosec} d_m. \quad . \quad . \quad . \quad (12a)$$

Other functions may be computed, in meters, by using $R_m$ for $R$ and $d_m$ for $\frac{1}{2}D$ in the formulas which follow, based upon the definition of the degree of curve as the angle at the center subtended by one 100-ft. chord, two 50-ft. chords, four 25-ft. chords, etc., depending upon the sharpness of curvature.

Approximate values may be found from our own tables. Thus, numerically, $R_m$ (in meters) $=0.2R$ for $D=2d_m$ in Table I. Also $L.C._m=0.2\ L.C.$, $M_m=0.2M.$, $E_m=0.2\ E$ and $T_m=0.2T$ for the values found from Table IX, when the table is entered with $D=2d_m$ as argument.

If the equivalent value of the degree of curve in the units we use is wanted, reduce $R_m$ to feet and in Table I find the corresponding value of $D$.

Table I*a* gives values of metric radii for curves up to 10 degrees, corresponding to a 30° 20′ curve as defined in Section **75**, if 10-ft. chords are used.

**76. The Length of Curve** ($L$) is found by dividing the angle at the center (which equals the intersection angle) by the degree of curve, the result being in chains and decimals of a chain. The number of $P.C.+L$ will give the station number of $P.T.$

EXAMPLE.—The $P.C.$ of a 4° curve having $I=26° 30'$ is at sta. 104+12.5. Find $L$ and the number of the $P.T.$ Here

$$L=\frac{26.5}{4}=6.625 \text{ chains.}$$

$104.125+6.625=110.75$; hence the number of $P.T.$ is $110+75$

**77. Use of the Table of Functions of a One-degree Curve.**—In the location of railway curves geometrical accuracy will frequently be of less importance than rapidity of field-work, so long as errors are kept within reasonable limits.

On tangents slight errors of alignment may readily be detected by the unaided eye, but on curves these are not so apparent. Moreover, it is not likely that the trackmen will keep curves up in the precise position of their location.

Table IX contains the most frequently used functions a 1° curve, and its use serves to greatly simplify and sho the computations of these functions for other curves. ordinary use for this purpose requires the assumption that functions vary inversely as the degree of curve, or directl the radius. This assumption is not so very violent if chord length used is made to vary with the degree of curv advised in Section **75**. Thus 100-ft. chords may be used curves not exceeding 7 degrees; 50-ft. chords for curves betw 7 and 14 degrees; 25-ft. chords for curves between 14 28 degrees; and 10-ft. chords for all sharper curves. Tab gives the values of the radii of chords up to 20 degrees, w radii were computed on this basis.

In computing Table IX the radius of a 1° curve was assu to be 5730 feet instead of the more precise value of 572 feet. This, not only for simplicity of computation, but because the approximate values of the functions found other curves by the use of the table, agree more closely the true values than would be the case if the value 572 had been used in computing the tabular quantities.

Table IX*a* contains correction factors, by the use of w the precise values of the *L.C.*, *M*, *E*, and *T* of any c may be found from the values given in Table IX when chord length employed in locating the curve is known.

Let $n$ = number of chord lengths used per degree of cu ($n=1$ when $c=100$ feet; $n=2$ when $c=50$ feet; $n=4$ w $c=25$ feet, and $n=10$ when $c=10$ feet). Let $(f\,\tfrac{1}{2}I)=$ sir vers $\tfrac{1}{2}I$, exsec $\tfrac{1}{2}I$ or tan $\tfrac{1}{2}I$ according as the precise value o *L.C.*, *M*, *E*, or *T* is wanted for the particular value of $c$ u Let $k$ be a factor defined by its use in the equation below:

$$R(f\,\tfrac{1}{2}I)=\frac{\frac{100}{2n}}{\sin\frac{1}{2}\frac{D}{n}}(f\,\tfrac{1}{2}I)=(1+k)\frac{5730}{D}(f\,\tfrac{1}{2}I),$$

from which
$$1+k=\frac{\frac{100}{2n}D}{5730\sin\frac{1}{2}\frac{D}{n}},$$

and, therefore,

$$\text{True } L.C.,\ M,\ E, \text{ or } T=\frac{\text{Tabular function}}{\text{Degree of curve}}(1+k).$$

**Example.**—Given a 10° curve run with 100-ft. chords through an angle $I=40°$, to find the true $T$ and $M$.

By Table IX, $T=\frac{4808.0}{10}=480.8$ feet, $M=\frac{1340.6}{10}=134.06$ feet.

By Table IX*a* the correction factor is $+0.00120$, and therefore the true $T=480.8(1.0012)=+481.38$, and the true $M=134.06(1.0012)=134.22$.

Had 50-ft. chords been used, as advised in Section **75**, the correction factor would have been only $+0.00024$, or one-fifth as much as when 100-ft. chords are used.

Table IX may also be used for finding the functions to employ when running metric curves, the tabular values being taken as meters instead of feet. The unit metric chord is 20 meters, and the degree as defined in Section **75a** is half the angle at the center for this chord, so we must enter Table IX with $5\times 2d_m=10d_m$ as argument. Thus for a 2° metric curve having $I=40°$, $M=\frac{345.6}{10\times 2}=17.28$ meters.

In the examples given in some of the sections which follow, the subscript 1 is written after the letters which designate the function referred to, in order to save space. Thus $T_1 \measuredangle 28°$ means the tangent distance for a 1° curve when $I=28$ degrees.

**78. Tables of Natural and Logarithmic Circular Functions.**—Many engineers prefer to work altogether by tables of natural sines, cosines, etc., and time may often be saved by their use. Nevertheless logarithmic tables are of frequent advantage, even in the field, and the more important ones, such as the logarithmic sines, cosines, tangents, and cotangents, together with the logarithms of numbers, are given in the back of the book along with the tables of natural functions.

**79. Given *R* and *C* to Find *D*.**

From equation (12),

$$\sin \tfrac{1}{2}D = \frac{\tfrac{1}{2}C}{R}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

**80. Given *I* and *R* (or *D*) to Find *T*.**

If $D$ is given, find $R$ by (12); then in Fig. 15 from triangle $OAB$ we get

$$T = R \tan \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

By Table IX.—Find the tabular value of $T$ for the given angle $I$; then

$$T = \frac{T_1}{D}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14a)$$

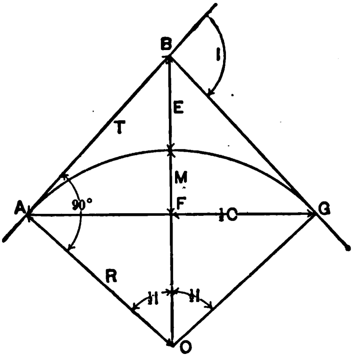


Fig. 15.

Example.—$I = 35° \ 40'$, $D = 4°$; required $T$.

By (14), $T = 1432.69 \tan 17° \ 50' = 460.91$ feet.

By (14$a$), $T = \frac{1843.4}{4} = 460.85$ feet, a result differing from the value found by the rigid method by only 0.06 foot.

**81. Given $I$ and $T$ to Find $R$ or $D$**

From (14),

$$R = \frac{T}{\tan \frac{1}{2}I} = T \cot \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Then by Table I the degree may be found.

By Table IX.

$$D = \frac{T_1}{T}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15a)$$

**82. Given $I$ and $D$ to Find the Long Chord $L.C.$**

First find $R$ by (12) or (12′), or by Table I; then from the triangle $OAF$ of Fig. 15,

$$AF = R \sin \tfrac{1}{2}I.$$

$$\therefore \ AG = 2AF = L.C. = 2R \sin \tfrac{1}{2}I \quad . \quad . \quad . \quad (16)$$

**By Table IX.**—Find the tabular $L.C.$ for the given angle $I$; then

$$L.C. = \frac{L.C._1}{D} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (16a)$$

**83. Given the Radius $R$ and any Chord $C$ to Find the Ordinate to the Curve at any Point.**

First Method.—In Fig. 16 let $HE$ be the chord $C$; $HK = a$ and $KE = b$, the segments into which it is divided by the ordinate $y$. Draw the radius through $K$; call the portion between chord and curve $y'$. By geometry,

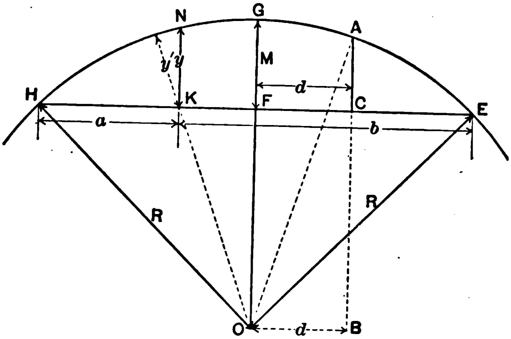


Fig. 16.

$$(2R - y')y' = ab,$$

from which

$$y' = \frac{ab}{2R - y'}.$$

But $y'$ is small compared with $2R$, and hence we write

$$y' = \frac{ab}{2R}. \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (a)$$

Now $y$ does not differ sensibly from $y'$ in the cases met with in practice, so we write

$$y = \frac{ab}{2R}. \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (b)$$

If we write $R = \frac{5730}{D}$, formula ($b$) becomes

$$y = \frac{abD}{2 \times 5730}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

Let $\frac{a}{100} = m$, $\frac{b}{100} = n$, and substitute in ($c$), giving

$$y = \frac{10000}{11460} mnD = 0.873mnD,$$

or very nearly

$$y = \tfrac{7}{8}mnD. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

$y$ is given in feet when $m$ and $n$ are in chains and decimals of a chain.

At the mid-point $F$, $m = n$, and $y = M$.

$$\therefore \; M = \tfrac{7}{8}n^2D. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

CAUTION.—Formulas (17) and (18), while very convenient for field use in passing obstructions, are liable to error when very long chords or large values of $D$ are used, since they give results that are too small.

If we write the arcs $HN$, $NE$ for $a$ and $b$, we shall get results that are too large, yet about as near the true values as by taking $m$ and $n$ to be the segments of the chord. To illustrate we will find a few values of $M$ and compare with the true values taken from Table V.

| Degree of Curve. | Length of Arc. | Mid-ord. by $M = \frac{7}{8}(HF)^2D$. | Mid-ord. by $M = \frac{7}{8}(HG)^2D$. | Mid-ord. by Table V. |
|---|---|---|---|---|
| 2....... | 2 stations. | 1.75 | 1.75 | 1.75 |
| 2....... | 6 " | 15.69 | 15.75 | 15.69 |
| 5....... | 2 " | 4.37 | 4.38 | 4.36 |
| 5....... | 6 " | 38.51 | 39.38 | 39.06 |
| 8....... | 2 " | 6.96 | 7.00 | 6.97 |
| 8....... | 4 " | 27.29 | 28.00 | 27.75 |
| 8....... | 5 " | 42.02 | 43.75 | 43.20 |
| 8....... | 6 " | 59.43 | 63.00 | 61.93 |

From this it appears we may use formula (18)—and (17) as well—taking either the segments of the arc or chord for curves not exceeding 4° with arcs up to 600 ft.; for curves from 4° to 6°

they may be used up to 500-ft. arcs, while for curves between 6° and 8° not more than 400 feet of arc may be taken.

SECOND METHOD.—First determine the mid-ordinate. In triangle $OEF$,

$$OF = \sqrt{R^2 - \tfrac{1}{4}C^2};$$

then

$$M = FG = R - \sqrt{R^2 - \tfrac{1}{4}C^2}. \quad . \quad . \quad . \quad . \quad . \quad (19)$$

To find ordinate $AC$ distant $d$ from the mid-point of $EH$, draw $OB = d$ parallel to $HE$; draw $AB$ at right angles to $HE$. Then

$$BA = \sqrt{R^2 - d^2}.$$

Therefore

$$CA = y = \sqrt{R^2 - d^2} - \sqrt{R^2 - \tfrac{1}{4}C^2}. \quad . \quad . \quad . \quad (20)$$

THIRD METHOD.—If the chord $C$ is short, we may regard the arc as an arc of a parabola, for which it is known that ordinates vary as the product of the segments into which they divide the chord. The mid-ordinate being known, we have

$$\frac{y}{M} = \frac{ab}{(\frac{1}{2}C)^2}$$

$$\therefore y = 4\frac{abM}{C^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

From formula ($b$) we have for $y = M$, $a = b = \frac{1}{2}C$,

$$M = \frac{(\frac{1}{2}C)^2}{2R} = \frac{C^2}{8R}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

The mid-ordinate for any other chord $C'$ is

$$M_1 = \frac{C'^2}{8R}.$$

Hence

$$\frac{M_1}{M} = \frac{C'^2}{C^2}.$$

$$\therefore M_1 = M\left(\frac{C'}{C}\right)^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

If $C' = \frac{1}{2}C$, this gives

$$M_1 = \tfrac{1}{4}M. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23')$$

This last relation affords an easy method of staking out a curve when the mid-ordinate of a given chord has been determined. First erect the ordinate $M$ at the mid point of the chord; then join the ends of chord with the extremity of the ordinate just measured; the lengths of these chords do not differ much from $\frac{1}{2}C$; at their mid-points erect ordinates equal to $\frac{1}{4}M$, giving points on the curve. Proceed in like manner for other points until a sufficient number have been located.

### 84. Given $R$ and $I$ to Find the External $E$.

In Fig. 17 $E = GB = OB - OG$.

But $OB = R \sec \frac{1}{2}I$ and $OG = R$.

$$\therefore \; E = R(\sec \tfrac{1}{2}I - 1) = R \operatorname{ex\,sec} \tfrac{1}{2}I. \quad . \quad . \quad . \qquad (24)$$

By Table IX.—Find $E$ for a 1° curve for an intersection angle $I$; then

$$E = \frac{E_1}{D}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (24a)$$

### 85. Given $T$ and $I$ to Find $E$.

In Fig. 17 draw $BC$ perpendicular to $AB$, and produce $AG$ to

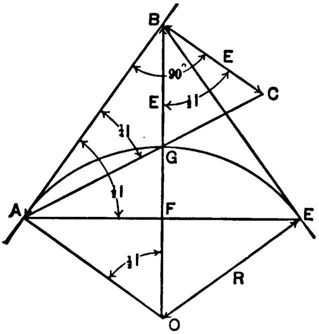


FIG. 17.

intersect $BC$ at $C$. $BC$ is parallel to $AO$, and the triangles $AGO$ and $CGB$ are similar; hence $BC = BG = E$. In the right triangle $ABC$, angle $BAC = \frac{1}{2}BAF = \frac{1}{4}I$. Therefore

$$E = T \tan \tfrac{1}{4}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (25)$$

Exercise.—Derive equation (25) from (24).

**86. Given $M$ and $I$ to Find $E$.**

From trigonometry,

$$\sec \tfrac{1}{2}I = \frac{1}{\cos \tfrac{1}{2}I}.$$

Insert this in (24) and we get

$$E = R\frac{1 - \cos \tfrac{1}{2}I}{\cos \tfrac{1}{2}I}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

But from Fig. 17, $M = R(1 - \cos \tfrac{1}{2}I)$. Substitute in ($a$):

$$E = \frac{M}{\cos \tfrac{1}{2}I} = M \sec \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

**87. Given $E$ and $I$ to Find $R$.**

From (24),

$$R = \frac{E}{\sec \tfrac{1}{2}I - 1} = \frac{E}{\text{ex sec } \tfrac{1}{2}I} = E\frac{\cos \tfrac{1}{2}I}{\text{vers } \tfrac{1}{2}I}. \quad . \quad . \quad (27)$$

**88. Given $I$ and $E$ to Find $T$.**

From (25),

$$T = \frac{E}{\tan \tfrac{1}{4}I} = E \cot \tfrac{1}{4}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad (28$$

**89. Given the Chord $C$ and Degree of Curve $D$ to Find the Chord Deflection Offset $d$.**

In Fig. 18 extend $EA$ to $H$, making $AH = EA = AB$; join $H$ and $B$ and draw $AK$ to the mid point of $HB$. Then

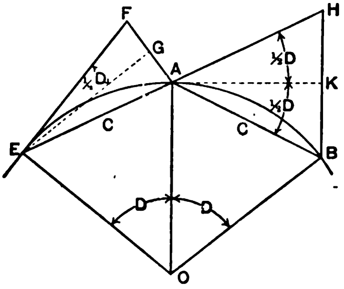


FIG. 18.

$$HK = KB = C \sin \tfrac{1}{2}D.$$

$$\therefore\ d = HB = 2C \sin \tfrac{1}{2}D. \quad . \quad . \quad . \quad . \quad . \quad (29)$$

When $C = 100'$,

$$d = 200 \sin \tfrac{1}{2}D. \quad \ldots \ldots \quad (29')$$

If we write $\sin \frac{1}{2}D = \frac{\frac{1}{2}C}{R}$ from (12) in formula (29), there results

$$d = \frac{C^2}{R}. \quad \ldots \ldots \quad (30)$$

For curves up to 7°, $C = 100'$; hence

$$d = \frac{10000}{R}. \quad \ldots \ldots \quad (30')$$

For curves from 7° to 14°, $C = 50'$; therefore

$$d = \frac{2500}{R}. \quad \ldots \ldots \quad (30'')$$

For $R$ write $\frac{5730}{D}$, and (30'), for $C = 100$, becomes

$$d = \frac{10000}{5730}D = 1.745D; \quad \ldots \ldots \quad (31)$$

and for $C = 50$, (30'') becomes

$$d = \frac{2500}{5730}D = .4363D = .873 \cdot \frac{D}{2}. \quad \ldots \quad (31')$$

EXAMPLE.—Find $d$ for a 6° curve, $C = 100$ feet.

By (29'), $d = 200 \times 0.05234 = 10.47$ feet.

By (30'), $d = \frac{10000}{955.4} = 10.47$ feet.

By (31), $d = 1.745 \times 6 = 10.47$ feet.

**90. Given the Chord $C$ and Degree of Curve $D$ to Find the Tangential Deflection Offset $t$.**

In Fig. 18 make $EF$ (tangent at $E$) equal to $EA$, and join $F$ with $A$. Draw $EG$ to the mid-point of $FA$. Angle $AEG = GEF = \frac{1}{4}D$; hence, from the figure,

$$AG = GF = C \sin \tfrac{1}{4}D.$$

$$\therefore t = 2C \sin \tfrac{1}{4}D. \quad \ldots \ldots \quad (32)$$

**When** $O = 100$ **feet,**

$$t = 200 \sin \tfrac{1}{4}D. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32')$$

Since $\frac{1}{4}D$ is small, we may write, without material error, $\sin \frac{1}{4}D = \frac{1}{2} \sin \frac{1}{2}D$; then, writing $\sin \frac{1}{2}D = \frac{\frac{1}{2}C}{R}$, as in **89**, we get

$$t = \frac{C^2}{2R}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

Making $C = 100$ ft. and writing $R = \frac{5730}{D}$ gives

$$t = \frac{10000}{2 \times 5730} D = 0.873D. \quad . \quad . \quad . \quad . \quad . \quad (33')$$

When $C = 50$ feet, (33) yields

$$t = .218D = .436 \times \frac{D}{2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (33'')$$

EXAMPLE.—Find $t$ for a 6° curve, $C = 100$ ft.

By (32') $\quad t = 200 \sin 1° 30' = 5.24$ ft.

By (33'), $\quad = .873 \times 6 = 5.24$ ft.

## 91. To Find the Subtangential Deflection Offset $t'$ for a Subchord $C'$

FIRST METHOD.—By formula (13) find the angle at the center subtended by the subchord $C'$; call this angle $D'$. From (32),

$$t' = 2C' \sin \tfrac{1}{4}D'. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

SECOND METHOD.—In Fig. 19, with $E$ as center strike the arcs $FG$ and $AH$, taking $EF = C'$ and $EA = C$; prolong $EG$ to $B$. Now assuming that the chords $C'$ and $C$ are proportional to their central angles we have

$$\frac{AB}{C'} = \frac{t}{C}. \quad . \quad . \quad . \quad (a)$$

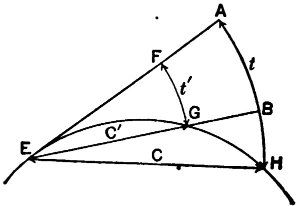


FIG. 19.

From the similar sectors $EFG$ and $EAB$, since $EB = C$,

$$\frac{C}{AB} = \frac{C'}{t'}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

By successive applications of (36) we have

$$\begin{aligned}
\text{for } n &= \tfrac{1}{2}, & z &= \tfrac{7}{8} \times \tfrac{1}{4} \times 4 = 0.88 \text{ feet} \\
n &= 1, & z &= \tfrac{7}{8} \times 1 \times 4 = 3.50 \text{ ``} \\
n &= \tfrac{3}{2}, & z &= \tfrac{7}{8} \times \tfrac{9}{4} \times 4 = 7.88 \text{ ``} \\
n &= 2, & z &= \tfrac{7}{8} \times 4 \times 4 = 14.00 \text{ ``} \\
n &= \tfrac{5}{2}, & z &= \tfrac{7}{8} \times \tfrac{25}{4} \times 4 = 21.88 \text{ ``} \\
n &= 3, & z &= \tfrac{7}{8} \times 9 \times 4 = 31.50 \text{ ``}
\end{aligned}$$

The last value of $z$ is in error by about 0.2 ft, but for setting stakes on construction this difference is not material so long as the alignment beyond this point does not depend on it. In setting track-centers the completed road-bed is available and the stakes may be set with the transit, in the usual way.

### 93. Difference in Length of a Circular Arc and its Long Chord.

FIRST METHOD.—Let the central angle be $a$ degrees. By (13), $\sin \tfrac{1}{2}a^\circ = \dfrac{c}{2R}$

Changing degrees to circular measure, $a$ (in $\pi$ meas.) $= \dfrac{\pi a^\circ}{180} = \dfrac{a^\circ}{57.3}$. The length of arc is $Ra = R\dfrac{a^\circ}{57.3}$. Then

$$\text{Arc} - \text{chord} = R\frac{a^\circ}{57.3} - c. \quad . \quad . \quad . \quad . \quad . \quad (37)$$

SECOND METHOD.—An easy approximation may be found as follows:

Referring to Fig. 17, $AE = c$, $GF = M$. Let $AG = b = \dfrac{c}{2} + x$. From the right triangle $AFG$

$$\left(\frac{c}{2} + x\right)^2 = \frac{c^2}{4} + M^2.$$

From which
$$x = \frac{M^2}{c + x}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

Neglecting the $x$ in denominator as small compared with $c$ gives

$$x = \frac{M^2}{c}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (b)$$

Then will $$2b - c = 2x = \frac{2M^2}{c}. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (38)$$

From Huygens' approximation to the length of a circular arc (see Williamson's Differential Calculus, p. 66), arc $= \frac{8b - c}{3}$. Therefore

$$\text{Arc} - \text{chord} = \frac{8b - c}{3} - c = \tfrac{4}{3}(2b - c). \quad . \quad . \qquad (c)$$

Inserting the value of $2b - c$ from (38) gives

$$\text{Arc} - \text{chord} = \frac{8M^2}{3c}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (d)$$

When the arc is not very great we may write $c = 100n_1$, where $n_1$ is the number of chains contained in the arc $AE$. From (18), remembering that $n_1 = 2n$,

$$M = 0.218 n_1^2 D.$$

Inserting these values of $c$ and $M$ in $(d)$,

$$\text{Arc} - \text{chord} = \frac{8}{3}\,\frac{(.218)^2 n_1^4 D^2}{100 n_1} = \frac{1}{800} n_1^3 D^2, \text{ nearly.} \quad . \quad . \qquad (39)$$

Example.—Find the difference in length of arc and chord of a 4° curve when $n_1 = 6$ stations.

The central angle is $4 \times 6 = 24°$; then, from Table IV, $c = 595.74$.

By (37),

$$\text{Arc} - \text{chord} = 1432.7 \times \frac{24}{57.3} - 595.74 = 4.34 \text{ ft.}$$

By (39),

$$\text{Arc} - \text{chord} = \frac{6 \times 6 \times 6 \times 4 \times 4}{800} = 4.32 \text{ ft}$$

Remark.—Formula (38) is interesting as showing what a comparatively small increase in length of line is caused by a considerable lateral deflection in alignment. For instance, a lateral deflection of 2000 feet is made at the mid-point of a line 40,000 feet long; what will be the increase in length?

By (38) the increase is $\frac{2(2000)^2}{40,000} = 200$ feet, giving for the increased length 40,200 feet.

### *B. Locating Simple Curves.*

**94. To Locate a Curve with the Chain by Offsets from Chords Produced.**

In Fig. 21 let the *P. C.* fall at *B*. If *BC* is a full chain, prolong the tangent *AB* to *H*, making $BH = BC$; *HC* will equal *t*, which may be calculated by (32′) or (33′). With *B* as center, strike an arc with radius *BH*, and with *H* as center and *t* as radius strike an arc; at *C*, where these arcs intersect, set a stake. Produce *BC* to *K*, making $CK = BC = CD$; strike the arc *KD* from *C* as center; make the chord $KD = d$, calculated from (29′), (30′), or (31). Set a stake at *D* and proceed in like manner for the other points until the *P. T.* is reached, where *FP* is made equal to *t*.

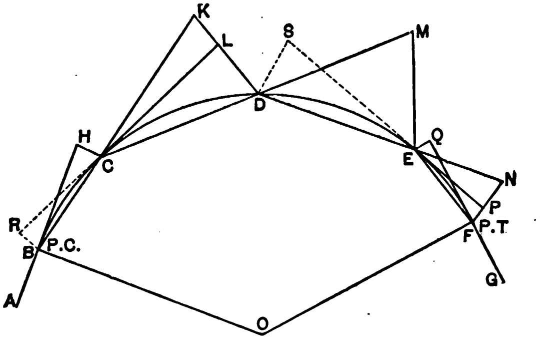


FIG. 21.

Usually the *P.C.* does not fall at a full station; then $HC = t'$, which may be found by (34) or (35). Using this value of $t'$, we locate *C* as above. At *B* make $BR = t'$, and prolong *RC* to *L*; make $LD = t$ and set a stake at *D*. *EM* will equal *d*, and may be located as before.

We may regard *KD* as equal to $KL + t$, and, finding, *KL*, measure $KD$ and set $D$ without locating $R$. To do this we have the similar triangles $BHC$ and $CKL$, from which

$$\frac{KL}{CK}=\frac{t'}{BC},$$

and therefore since $KC = CD$,

$$KL = t'\frac{CD}{BC}.$$

In like manner at $F$ we have

$$PN = t\frac{EF}{ED}, \quad \text{and} \quad FP = t_1'$$

hence

$$NF = PN + t_1'.$$

Make $EQ = t_1'$, prolong $QF$, and we have the tangent at $F$.

**Example.**—Given the $P.C.$ of a 5° curve at 106 + 20 and the angle of intersection 22°, to locate the curve.

Here $$L = \frac{22}{5} = 4.4 \text{ stations.}$$

Therefore the number of the $P.T.$ is

$$106.20 + 4.4 = \text{sta. } 110 + 60.$$

$BC$ in this case is 80 ft., and by (33′)

$$t = 0.873 \times 5 = 4.37 \text{ ft.}$$

By (35), $$t' = 4.37 \times \left(\frac{80}{100}\right)^2 = 2.80 \text{ ft.}$$

Set off $HC = 2.80$ ft., and at $D$ make

$$KD = 2.80 \times \frac{100}{80} + 4.37 = 7.87 \text{ ft.}$$

At $E$ make $ME = d = 8.72$ by (31). This will be at sta. 109; at 110 set a stake by offsetting 8.72 ft. The last chord is 60 long, and hence the offset

$$NF = 4.37 \times \frac{60}{100} + 4.37 \times \left(\frac{60}{100}\right)^2 = 2.62 + 1.57 = 4.19 \text{ ft.}$$

Make $EQ = 1.57$ ft., and prolong $QF$, the terminal tangent.

### 95. To Locate a $D$ Degree Curve by Offsets from Tangent.

Let $AM$, Fig. 22, be tangent at $A$, and $E$, $F$, $G$, etc., points on the curve. The offsets $BE$, $CF$, etc., may be found from formula (36),

$$z = \tfrac{7}{8}n^2D,$$

either by taking equal intervals, $AB$, $BC$, $CM$ along the tangent or by taking $E$, $F$, $G$, etc., at regular stations around the curve and using the arc length instead of the tangent.

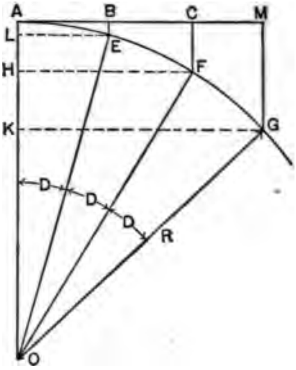


FIG. 22.

When the arc $AG$ is large, or strict accuracy is required, we proceed to find the offsets at regular stations and the lengths of $AB$, $AC$, etc. First find $R$ from (12) or (12′); then from triangle $OEL$,

$$BE = AL = R(1 - \cos D) = R \text{ vers } D,$$

$$AB = LE = R \sin D.$$

In like manner

$$CF = AH = R(1 - \cos 2D) = R \text{ vers } 2D,$$
$$AC = HF = R \sin 2D,$$

and so on for any number of stations.

Should $A$ fall at a plus station, we first find the angle $D_1$ at the center, then

$$BE = R \text{ vers } D_1,$$
$$AB = R \sin D_1,$$
$$CF = R \text{ vers } (D_1 + D),$$
$$AC = R \sin (D_1 + D),$$
$$\text{etc.} = \text{etc.}$$

The ordinates $BE$, $CF$, etc., are evidently equal to the mid-ordinates for long chords $2LE$, $2HF$, etc.; hence we can, if $A$, $E$, $F$, and $G$, fall at full stations, take them direct from Table V; then take the long chords from Table IV and dividing these by 2, get the required coordinates.

Example.—Locate three stations of a 4° curve by offsets every 50 ft. on *curve*.

Referring to Table V, the required offsets are 0.87, 3.49, 7.85, 13.94, 21.77, and 31.31. By Table IV the distances measured along tangent are 50.0, 99.94, 149.76, 199.39, 248.78, and 297.87. With these values we can set out the curve either way from *A*.

Had we used formula (36) we should have had for the values of the offsets 0.87, 3.50, 7.88, 14.00, 21.87, and 31.50.

### 96. To Locate a Curve by Offsets from a given Long Chord.

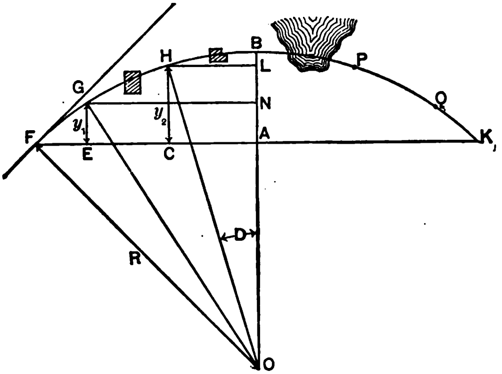


Fig. 23.

Let *FK*, Fig. 23, be the given chord. We may compute the offsets $y_1$, $y_2$ . . . $M$ by the methods of 83—of which formula (17),

$$y = \tfrac{7}{8}mnD,$$

is the most convenient, within the limits of its applicability—and setting off these ordinates, locate the curve.

Or we may set off the mid-ordinate $M = R \text{ vers } FOA$ at *A*, and at *C* set off $y_2 = M - R \text{ vers } D$, making

$$AC = HL = R \sin D.$$

*GE* will be

$$y_1 = M - R \text{ vers } 2D, \quad \text{and} \quad AE = R \sin 2D.$$

Another Method is to find the angle *KOF* at the center, and by Table IX determine $BA = M$; then by Tables V and IV determine $BL$, $BN$, $LH$, and $NG$. Then $HC = M - BL$, which set off at $C$, and other points in like manner.

EXAMPLE.—Given the $P.C.$ of a 4° curve at station 160 + 75, the angle between tangent and chord = 9°, required the offsets necessary to locate the curve.

Here $$I = 2 \times 9 = 18°.$$

$$\therefore \quad L = \frac{18}{4} = 4.50 \text{ stations.}$$

Hence the $P.T.$ falls at 160.75 + 4.50 = sta. 165 + 25. The mid-point on curve $B$ falls at sta. 163. By Table IX,

$$M = \frac{70.54}{4} = 17.64 \text{ ft.}$$

By Table V the mid-ordinate for two stations of a 4° curve is

$$BL = 3.49.$$

Hence $$HC = 17.64 - 3.49 = 14.15.$$

By Table IV, $$HL = AC = 99.94 \text{ ft.}$$

Measure $AC = 99.94$ ft., and set off $CH = 14.15$ ft., and drive a stake at $H$. In like manner find

$$GE = 3.70 \quad \text{and} \quad AE = 199.39 \text{ ft.}$$

The points $P$ and $Q$ are also located by means of the coordinates just determined.

If $B$ had fallen at an odd station, the curve could have been located in the same manner, $H$ and $P$ being 100 ft. from $B$, $G$ and $Q$ 200, etc.

### 97. To Locate a Curve with Transit and Chain when the Degree $D$ or Radius $R$ is Known.

If $R$ is given, determine $D$ by (13); then, since the angle in the circumference of a circle is half the angle at the center subtended by the same chord, we may locate points on the curve by successive deflections from the tangent.

In Fig. 24 let the $P.C.$ be at $A$, at which point set the transit, and with the vernier-plates clamped at zero place the telescope in tangent either by sighting the $P.I.$ or by backsighting to some point in the tangent Deflect from the tangent half the angle at the center for the sub-chord or chord, and direct the head chainman into line while the rear chainman holds his end of the chain at the transit, the chain being kept taut. The stakeman drives a stake at the point where the head chainman's flag rested, and the rear chainman advances to this point. Deflect $\frac{1}{2}D$ from the chord $AB$ just run, and while the rear chainman holds his end of the chain at $B$ direct the head chainman into line at $C$. Other points are located by deflecting an additional $\frac{1}{2}D$ for each chord length measured, until a point $E$ is reached to which it is desirable to move the transit. The angle $FAE$ should not exceed about 15°. Move the transit to $E$, backsight to $A$, and deflect $FEA = EAF$, when the telescope will be in tangent, and the curve can be continued until it is again necessary to move the transit. At the *P.T.* put the telescope in tangent by backsighting to the point last occupied by transit and deflecting the tangential angle as at $E$. The line may now be continued.

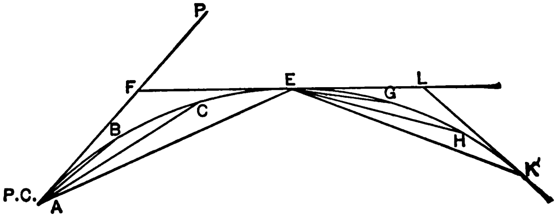


FIG. 24.

**98. The Index-angle** is read on the vernier-plate, and is the angle between the tangent to the curve at the *P.C.* and any other line passing through a point on the curve when the telescope is directed along this line. It is most frequently taken as the angle between the initial and any subsequent tangent to the curve. Thus at $E$ the index-angle equals $EFP = 2FAE$. At any point on the curve the index-reading in tangent may be found by the following rule, which may be easily deduced from a figure:

*From double the index-angle that fixed the point subtract the index-angle in tangent at the last point; the remainder is the index-angle required.*

**99. Subdeflection-angles** may be found by (13) rigidly, or approximately (and with sufficient accuracy except when $D$ is very large) by assuming the central angles to be proportional to their chords. Thus on a 4° curve the central angle for a sub-chord of 25 ft. would be 1°, and the subdeflection-angle 30′.

**Example.**—Locate a 4° curve to left when the *P.C.* is at sta. 81 + 25 and $I = 32° 36'$.

Here $$L = \frac{32.6}{4} = 8.15 \text{ chains.}$$

Hence the *P.T.* will fall at 81.25 + 8.15 = sta. 89 + 40. The first sub-chord is 75 ft. long, and the first deflection-angle will be found by (13).

$$\sin \tfrac{1}{2}\delta = \frac{37.5}{1432.7} = 0.02617$$

$$\therefore \tfrac{1}{2}\delta = 1° \, 30'.$$

By the approximate rule, since $\frac{1}{2}D = 2°$,

$$\frac{\frac{1}{2}\delta}{2} = \frac{75}{100},$$

whence $\frac{1}{2}\delta = 2 \times \frac{3}{4} = 1° \, 30'$ as before.

With transit at *P.C.* deflect 1° 30′ from tangent, measure 75 feet, and set sta. 82. Then a deflection of 3° 30′ will determine 83, 5° 30′ sta. 84, 7° 30′ sta. 85. Now remove transit to 85, and with vernier at 7° 30′ backsight to 81 + 25. Reverse telescope and set vernier at 15° 00′, when the telescope will be in tangent. An index angle of 17° will fix 86, and so on.

The last chord will be only 40 feet long, for which the sub-deflection-angle is $\frac{40}{100}$ of 2°, that is, 48′. The index-angle fixing the *P.T.* is therefore 23° 48′.

To get in tangent at 89 + 40 backsight to sta. 85, with vernier at 23° 48′; then by the rule of **98** the index-reading is $(23° \, 48') \times 2 - 15° = 32° \, 36' = I$. Set the vernier at this reading and run tangent.

Caution.—It is not good practice to set more than 4 or 5 stations on curve from any one point. Mr. Shunk gives the limiting angle to be deflected from tangent as 20°, and says 15° should rarely be exceeded. (*Field Engineer*, p. 82.)

**100. The Transit Notes** may be conveniently kept in the form below, which shows the notes for the last example.

When possible the tangents should be run to intersection, the angle *I* measured, and the tangent distance calculated. Then

| Station. | | Deflection-angle. | Index-reading. | Index in Tangent. | Calculated Course | Magnetic Course. | Remarks. |
|---|---|---|---|---|---|---|---|
| 90 | | | | | | | |
| +40 | ⊙ *P.T.* | 0° 48′ | 23° 48′ | 32° 36′ | N 27° 36′ E | N 27° 30′ E | |
| 89 | | | 23° 0′ | | | | |
| 88 | | | 21° 0′ | | | | |
| 87 | | | 19° 0′ | | | | |
| 86 | | | 17° 0′ | | | | |
| 85 | ⊙ | | 7° 30′ | 15° 0′ | | | |
| 84 | | | 5° 30′ | | | | |
| 83 | | 2° 0′ | 3° 30′ | | | | |
| 82 | | 1° 30′ | 1° 30′ | | | | 4° C.L.; *P.I.* set. *I* = 32° 36′; *T* = 418.9 ft. |
| +25 | ⊙ *P.C.* 4° C.L. | 0° 0′ | 0° 0′ | 0° 0′ | | | |
| 81 | | | | | N 60° 12′ E | N 60° 10′ E | |

measure along tangents and set *P.C.* and *P.T.* from the *P.I.* When the curve is run in, the position of the *P.T.* thus found should agree with the one set from the *P.I.* If the error is greater than the circumstances of the case permit, the curve must be rerun and tangents remeasured.

**101. Another Form of Notes**, and in some respects a better one than the above, is given below. The index-readings are computed as though the entire curve were run from the *P.C.* The notes for the last example would appear as below:

| Station. | | Deflection-angle. | Index-reading. | Total Angle. | Calculated Course. | Magnetic Course. | Remarks. |
|---|---|---|---|---|---|---|---|
| 90 | | | | | | | |
| +40 | ⊙ *P.T.* | 0° 48′ | 16° 18′ | 32° 36′ | N 27° 36′ E | N 27° 30′ E | |
| 89 | | | 15° 30′ | | | | |
| 88 | | | 13° 30′ | | | | |
| 87 | | | 11° 30′ | | | | |
| 86 | | | 9° 30′ | | | | |
| 85 | ⊙ | | 7° 30′ | | | | |
| 84 | | | 5° 30′ | | | | |
| 83 | | 2° 0′ | 3° 30′ | | | | |
| 82 | | 1° 30′ | 1° 30′ | | | | 4° curve left; *P.I.* set. *I* = 32° 36′; *T* = 418.9 ft. |
| +25 | ⊙ *P.C.* 4° C.L. | 0° 0′ | 0° 0′ | | | | |
| 81 | | | | | N 60° 12′ E | N 60° 10′ E | |

The computations are all made before beginning the work, and the notes have the advantage of permitting the tracing of the curve either way from the instrument without additional computations. Suppose the transitman to have run the curve from the *P.C.* to sta. 85, to which point he removes the instrument. He there sets the vernier at 0°—the angle on limb when telescope was in tangent at the *P.C.*—then sighting the *P.C.* he reverses the telescope and deflects to 9° 30′, which will fix sta. 86. Had the tangent at 85 been desired, a reading of 7° 30′—the angle that located that point—would have put the telescope in the plane desired. A reading of 11° 30′ fixes 87, and so on to the *P.T.* Removing to the *P.T.*, the plates are clamped at 7° 30′, and a backsight to sta. 85 taken; then deflecting to 16° 18′, the telescope is in tangent at the *P.T.* Had it been desirable to set 84 from 85, a reading of 5° 30′ would fix that point; others may be found in the same manner.

Any convenient form of notes, which are intelligible to another engineer who may have to retrace the curve, may be used, but it is desirable that some general form should be employed. Either of the preceding forms seems to meet ordinary requirements.

## *C. Obstacles.*

### 102. To Pass an Obstacle on a Curve.

FIRST. *Suppose the obstacle to be one obstructing vision at one station only.*

In Fig. 25 suppose transit set at *A*, and *B* and *C* located from that point, but the next full station, *H*, to be invisible from *A*.

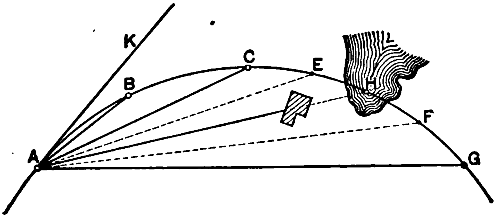


FIG. 25.

Set a plus station at *E*, as near the obstruction as may be convenient, then set *F* 100 feet from *E*. Next make $FG = 100 - CE$, and locate *G* with the corresponding deflection-angle. Other stakes may be set beyond *G*, or the transit may be removed to that point and the curve beyond traced.

SECOND. *Suppose the line of sight obscured for more than one station, as in Fig.* 26.

If transit is at $A$, deflect an angle $HAB$ that will clear all obstructions, and at the same time cause $B$ to fall at a full station. Then by Table IV, Table IX, or by formula (16) calculate the long chord $AB$; measure $AB$ and move transit to $B$; then deflect the angle $ABC = BAH$ when the telescope will be in tangent. The curve may now be run both ways from $B$.

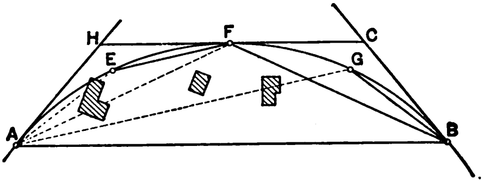


FIG. 26.

If it happen that some stations, as $E$ and $F$ in the figure, are still invisible, they may be located by offsets from chord or tangent.

EXAMPLE.—Let the curve be a 3° curve to right; angle $HAB = 7° 30'$, the deflection-angle for 5 stations. By Table IV the long chord is 498.63 feet, which can now be measured and a hub set at $B$; then making angle $CBA = 7° 30'$, the telescope will be in tangent and the curve can be traced either way.

### 103. To Locate a Curve when the *P. C.* is Inaccessible.

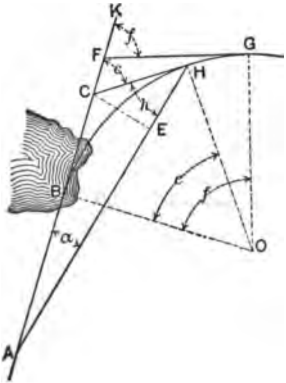


FIG. 27.

In Fig. 27 let the *P.C.* at $B$ be inaccessible; it is desired to reach a point $H$ on accessible ground.

FIRST METHOD. — Assume a point $H$ on the curve such that a line $AH$ from an accessible point $A$, on tangent, will clear the obstacle; for convenience $H$ should be at a full station. The arc $BH$ and central angle, which equals $HCF$, are then known. Calculate $BC = T$ by (14) or (14*a*); then since $AB$ is known, $AC, = AB + BC$, is known.

Now in triangle $ACH$, from trigonometry,

$$\frac{\tan \frac{1}{2}(h - a)}{\tan \frac{1}{2}(h + a)} = \frac{AC - CH}{AC + CH}$$

But $(h + a) = c$; hence

$$\tan \tfrac{1}{2}(h - a) = \frac{AC - CH}{AC + CH} \tan \tfrac{1}{2}c. \quad . \quad . \quad . \quad (40)$$

Then $\frac{1}{2}(h + a) + \frac{1}{2}(h - a) = h$, the larger angle, and $\frac{1}{2}(h + a) - \frac{1}{2}(h - a) = a$, the smaller angle. $AH$ may be found by the law of sines, or by drawing $CE$ perpendicular to $AH$, when

$$AH = AC \cos a + CH \cos h. \quad . \quad . \quad . \quad . \quad (41)$$

**Example.**—The *P.C.* of a 4° curve is at sta. 141 + 25, and it is desired to reach the point $H$ from sta. 139 on tangent.

Suppose $H$ be assumed to fall at sta. 147; the curve length is $L = 147 - 141.25 = 5.75$ chains. Then angle $c = 5.75 \times 4 = 23^\circ\ 0'$. By Table IX the tangent distance for a 1° curve is $T_1 \measuredangle 23^\circ = 1165.8$ ft.

By (14*a*), $$T = \frac{1165.8}{4} = 291.45 \text{ ft.}$$

Now $$AC = 291.45 + 225 = 516.45 \text{ ft.},$$
and

$$AC + CH = 516.45 + 291.45 = 807.90,$$

while

$$AC - CH = 225 \text{ ft.};$$

hence, by (40),

$$\tan \tfrac{1}{2}(h - a) = \frac{225}{807.9} \times 0.20345 = 0.05666 = \tan 3^\circ\ 15'.$$

Therefore

$$h = 11^\circ\ 30' + 3^\circ\ 15' = 14^\circ\ 45',$$

and

$$a = 11^\circ\ 30' - 3^\circ\ 15' = 8^\circ\ 15'.$$

By (41),

$$AH = 516.45 \times 0.98965 + 291.45 \times 0.96705 = 793.0 \text{ ft.}$$

At $A$ deflect 8° 15′ from tangent, measure 793.0 ft. and set a hub; move to this point, backsight to $A$ and deflect 14° 45′ into tangent, then trace in the curve.

SECOND METHOD.—If $F$, any assumed point in tangent, is visible from $A$, $AF$ may be measured by some indirect method; then $AF - AB = T$. The tangent for a 1° curve having same intersection-angle, $KFG$, is $T_1 = T \times D$; find this value of $T_1$ in Table IX and take out the corresponding value of $I$. With transit at $F$ deflect the angle $KFG$, measure $FG = FB = T$, and set hub at $G$. The station number of $G$ is found by dividing the central angle, $= KFG$, by the degree of curve $D$. Move to $G$ and trace the curve.

EXAMPLE.—Let $AF$ measure 490.5 ft. from sta. 139 of the last example. Then $AB = 225$ ft., and $BF = 490.5 - 225 = 265.5$ ft. $265.5 \times 4 = 1062$ ft., which by Table IX is the value of $T_1$ for $I = 21°$. Set transit at $F$, deflect 21°, and measure $FG = 265.5$ ft.

$$L = \frac{21}{4} = 5.25 \text{ chains};$$

hence $G$ will fall at $141.25 + 5.25 =$ sta. $146 + 50$. Move to $G$ and run the curve both ways.

THIRD METHOD.—In Fig. 28 let the inaccessible $P.C.$ be at $B$, and let it be required to reach $E$ from a point $C$ on the curve prolonged backwards from $B$.

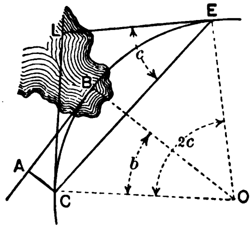


FIG. 28.

At a given point $A$ on tangent calculate the tangent offset by (36) or the methods of **95**, then set this off at right angles to $AB$; set the transit at $C$ and turn off $ACL = 90° - COB$, when the telescope will be in tangent at $C$. $COB$ may be found from Table IX by multiplying $AC$ by the degree of curve and taking half the intersection-angle corresponding to the mid-ordinate that equals this product. Now deflect and measure $ECL$, then by (16) or (16$a$) calculate $CE$, which measure. Move to $E$ and deflect $LEC = ECL$ and the telescope will be in tangent. The central angle $BOE = 2LEC - BOC$, from which the arc $BE$ and number of sta. $E$ may be found.

EXAMPLE.—Take the same example as in the last two cases. $A$ is at sta. 139, $B$ at $141 + 25$; hence $AB = 2.25$ stations.

By (36), $z = AC = \frac{7}{8} \times (2.25)^2 \times 4 = 17.72$ ft.

Or by Table IX the angle corresponding to the long chord $(2 \times 2.25) \times 4 = 1800$ ft. is 18° 4′, for which the mid-ordinate is 71.06 ft. For our 4° curve the mid-ordinate will be $\frac{71.06}{4} = 17.77$ ft., which equals $AC$ and agrees closely enough with the value for $z$ above.

Make angle $BAC = 90°$, and measure $AC = 17.72$ ft. Move to $C$ and sight to $A$, then make angle $ACL = 90° - (9° 2') = 80° 58'$. Suppose an angle $LCE = 16° 1'$ to clear the obstacle. By formula (16),

$$CE = 2R \sin (16° 1') = 2 \times 1432.7 \times 0.27592 = 790.6 \text{ ft.}$$

Measure along $CE$ 790.6 ft. and set a hub; move to $E$ and run the curve.

$CE$ might have been found by means of Table IX, for the long chord of a 1° curve having $I = 2LCE = 32° 2'$ is 3162.0 ft.; divide this by 4 and there results $CE = 790.5$ ft.

### 104. To Pass to Tangent when the *P.T.* is Inaccessible.

This is just the reverse of the preceding problem, and may be accomplished by reversing the processes described above.

When the *P.T.*, however, falls in or beyond a river or lake obstructing the ordinary methods of indirect measurement, the case merits a special solution.

First Method.—In Fig. 29 let the transit be at $A$, and $B$ the *P.T.* From the known station numbers of $A$ and $B$ the length of curve and angle $I$ may be found; then, by (14), $AC = R \tan \frac{1}{2}I$, or, by (14$a$), $AC = \frac{T_1 \measuredangle I°}{D}$.

Move to $C$ and deflect the angle $I$; set a stake $F$, and one at some other accessible point $E$; measure angle $ECF = c$. Move to $F$ and measure the angle $EFC$ and the side $EF$; then in triangle $ECF$ angle $e = 180° - (c + f)$; by trigonometry

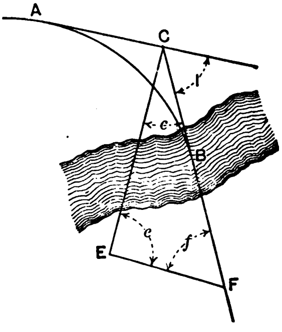


Fig. 29.

$$CF = \frac{\sin e}{\sin c} \cdot EF. \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

Since $BC = AC$, there results $BF = CF - AC$; and as the station number at $B$ is known, that at $F$ becomes known, and the line may be continued.

If $B$ is not the *P.T.*, measure back the distance $FB$, set transit at $B$, and continue the curve.

EXAMPLE.—Let the *P.T.* of a 2° *C.L.* fall at sta. 205 + 50—an inaccessible point; suppose $A$ at sta. 200, angle $c = 40°$, $f = 80°$, $EF = 310$ ft.

Here $\quad I = 5.50 \times 2 = 11°\ 0'$, and $\quad e = 60°$.

By (14*a*), $\quad T = \frac{551.74}{2} = 275.87$ ft.

From (42), applying logarithms,

$$\log CF = 2.49136 + 9.93753 - 9.80807 = 2.62082.$$

Whence $CF = 417.7$ ft. Then $BF = 417.7 - 275.87 = 141.8$ ft.; therefore the number of $F$ will be 206 + 91.8.

SECOND METHOD.—In Fig. 30, with the transit at any point $A$ on the curve, assume a long chord $AB$ and calculate the angle $CAB$; deflect this angle from the tangent $AC$, and set a point $E$ beyond obstruction; set also a stake at $C$ in tangent.

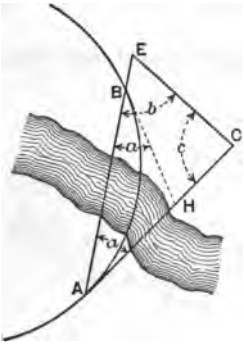


FIG. 30.

Move to $E$ and measure $AEC$ and side $EC$. Compute $AE$ from the triangle $AEC$. If this is greater or less than the length of the long chord $AB$, take their difference $BE$ and set a hub at $B$. With the transit at $B$ trace out the curve.

EXAMPLE.—Given $A$ at sta. 210 of a 3° C. L., angle $a = 12°$, $b = 92°$, $EC = 181$ ft. Then $c = 76°$, and by solving the triangle $AEC$, $AE = 844.7$ ft. By Table IX the long chord of a 1° curve for $I = 24°$ is 2382.6 ft.; therefore $AB = \frac{2382.6}{3} = 794.2$ ft. Now will $EB = 844.7 - 794.2 = 50.5$ ft., which is the distance along $EA$ that transit must be moved *back* from $E$.

**105. Given the Perpendicular $p$ from a Point to a Tangent, to Find the Point on Tangent at which to Begin a Curve of Given Radius which will Pass through the Given Point.**

First Solution.—In Fig. 31 let $P$ be the point, $BP$ the perpendicular. We have to find $BA = x$.

From $P$ draw $PC$ parallel to $AB$; then in triangle $OPC$

$$R^2 = x^2 + (R - p)^2.$$

From which

$$x = \sqrt{2Rp - p^2}. \quad . \quad (43)$$

Second Solution.—Consider $p = AC$ as the mid-ordinate for a long chord $= 2x$; then $p \times D$ = the mid-ordinate for a 1° curve for a central angle equal $2a$.

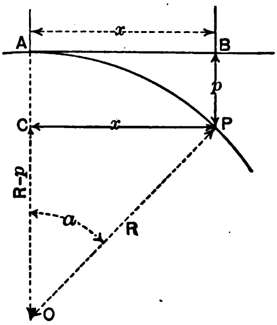


Fig. 31.

The corresponding long chord may be taken from Table IX. Then

$$x = \frac{1}{2}\frac{L.C._1}{D} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (43a)$$

Example.—Given $p = 30$ ft., $D = 4°$ ($R = 1432.7$), to find $x$.

By (43), $\quad x = \sqrt{85,962 - 900} = 291.65$ feet.

By the second method,

$$30 \times 4 = 120,$$

the mid-ordinate for a 1° curve corresponding to an angle of 23° 29′, for which the long chord is 2332.6. Now, by (43$a$),

$$x = \frac{1}{2} \times \frac{2332.6}{4} = 291.6 \text{ feet.}$$

**106. In Fig. 31, Given $x$ and $p$ to Find the Radius of a Curve Tangent to $AB$ at $A$ and Passing through $P$.**

From (43), $\quad R = \frac{x^2 + p^2}{2p} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$

### 107. Given the Location of a Point *P* referred to the *P. I.* to Find the Radius of a Curve through *P* which will Unite the Given Tangents.

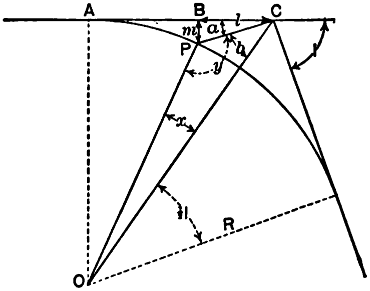


FIG. 32.

In Fig. 32 suppose $BC = l$, $BP = m$ known, and angle $a$ calculated; or $PC$ and $a$ may be measured on the field.

From triangle $CAO$,

$$b = 90° - (a + \tfrac{1}{2}I), \quad \text{and} \quad CO = R \sec \tfrac{1}{2}I.$$

Now from triangle $PCO$,

$$\sin y = \frac{CO}{PO} \sin b.$$

Inserting values of $PO$ and $CO$,

$$\sin y = \frac{R \sec \frac{1}{2}I}{R} . \sin b = \sec \tfrac{1}{2}I . \sin b = \frac{\sin b}{\cos \frac{1}{2}I}, \quad . \quad (45)$$

an equation from which the unknown $R$ has disappeared. **Next,** from the same triangle, since $x = 180° - (b + y)$,

$$R = \frac{\sin b}{\sin x} . PC. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (46)$$

When $I = 90°$, it can easily be shown that

$$R = l + m + \sqrt{2lm}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (47)$$

**108. To Locate a Tangent to a Curve from an Outside Point.**

FIRST METHOD.—In Fig. 33 let $P$ be the point and $AHB$ the curve. Run a trial-line $PA$ cutting the curve in $A$ and $B$. Measure $PA$ and $AB$; or measure $PA$ and angle $a$ between the chord $AB$ and tangent $AL$. Then

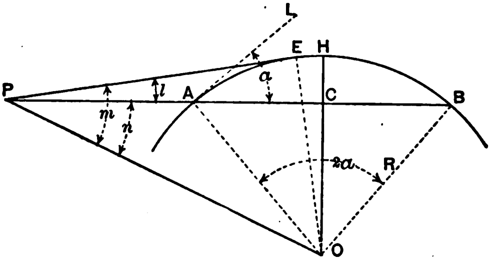


FIG. 33.

$$AB = 2AC = 2R \sin a,$$

$$OC = R \cos a.$$

By geometry, $PE = \sqrt{PA \times PB}$, $PE$ being the required tangent. From the figure,

$$\tan n = \frac{CO}{CP}$$

$$\tan m = \frac{R}{PE}.$$

At $P$ deflect the angle $l = m - n$ from $PA$ and run the tangent.

SECOND METHOD.—In Table IX find the long chord for a central angle $2a$; then

$$AB = 2AC = \frac{L.C._1}{D},$$

$$CH = \frac{M_1}{D},$$

and $$CO = R - CH.$$

We may now proceed as before.

### 109. To Run a Tangent to Two Located Curves of Contrary Flexure.

FIRST CASE.—In Fig. 34 let *FK* and *LE* be the curves, and $KL = p$ measured on the ground.

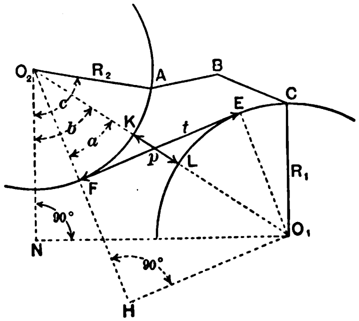


FIG. 34.

Let $FE = t$ be the required tangent.

Draw $O_1H$ parallel and $O_2H$ perpendicular to *FE*; from the triangle $O_1HO_2$, since $FH = R_1$,

$$(R_1 + R_2 + p)^2 = (R_1 + R_2)^2 + t^2 ;$$

whence $$t = \sqrt{2(R_1 + R_2)p + p^2}. \quad . \quad . \quad . \quad (48)$$

Also, $$\cos a = \frac{R_1 + R_2}{R_1 + R_2 + p}. \quad . \quad . \quad . \quad . \quad . \quad (49)$$

The arcs *FK* and *LE* may be found from the angle *a* and the known curvatures, after which the points *F* and *E* may be set.

If *t* is given and *p* required, it may easily be found from (48).

SECOND CASE. *p not known.*

Set the transit at a point *A* on one curve and note the bearing of the tangent to the curve at that point (see Fig. 34); the bearing of the radius $O_2A$ differs from this by 90°. Run a line *ABC* of one or more courses to intersect the other curve at *C*. Note the bearings and lengths of these courses and the bearing in tangent at *C*, from which calculate the bearing of $CO_1$. $R_1$ and $R_2$ being known, the latitudes and departures are next calculated. Let $O_2N$

be the sum of the northings or southings, $O_1N$ the sum of the eastings or westings; from the triangle $O_1O_2N$,

$$\tan b = \frac{O_1N}{O_2N},$$

and $$O_1O_2 = \sqrt{\overline{O_1N}^2 + \overline{O_2N}^2}.$$

As before, $FE$ is the required tangent and $O_2H$ perpendicular, while $O_1H$ is parallel thereto.

$$\cos a = \frac{R_1 + R_2}{O_1O_2}.$$

Angle $FO_2N = b - a$ is the bearing of $O_2F$, while $AO_2F = c - b + a$ is the angle of retreat from the known point $A$ to $F$, where the tangent may be run. The length of $t = O_1H$ is

$$t = O_2O_1 \sin a.$$

### *D. Change of Location.*

**110. To Locate a Curve Parallel to a Given Curve.**

Let $p$ be the perpendicular between parallel tangents, and suppose $ABC$ located (see Fig. 35). If there are no restrictions as to the position of the points $E$, $F$, and $G$ on the second curve, we may calculate the new degree of curve $D_1$ for a radius $R_1 = R + p$, by (13), and trace the curve from any point, as $E$. Thus

$$\sin \tfrac{1}{2}D_1 = \frac{50}{R_1} = \frac{50}{R + p}.$$

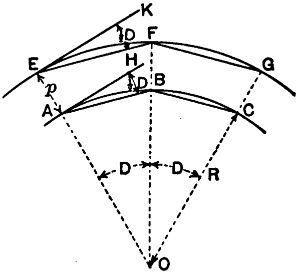


Fig. 35.

If, however, points on the radii through $A$, $B$, and $C$ are wanted, they are gotten by using the same degree of curve $D$ and computing the length of chord $FE$. From similar triangles,

$$\frac{EF}{R_1} = \frac{AB}{R} = \frac{100}{R},$$

whence

$$EF = 100\frac{R_1}{R} = 100\frac{R+p}{R} = 100\left(1+\frac{p}{R}\right). \quad . \quad . \quad (50)$$

Had *EFG* been the located curve, with radius *R*, we should have had

$$AB = 100\frac{R-p}{R}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

**111. To Change the *P.C.* of a Located Curve so that *P.T.* will Fall in a Given Tangent Parallel to Terminal Tangent of Located Curve.**

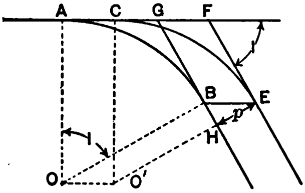


FIG. 36.

Let *AB*, Fig. 36, be the located curve; *FE*, the tangent in which the *P.T.* must fall.

Let the distance between tangents be $HE = p$.

Draw *BE* and *OO'* parallel to *AF*; evidently $AC = OO' = BE$, *O'* being the new position of center.

In triangle *BEH*,

$$BE = AC = \frac{p}{\sin I} = p \operatorname{cosec} I. \quad . \quad . \quad . \quad . \quad (52)$$

Set the new *P.C.* by measurement from *A*, and run the curve *CE*. Any system of straight lines and curves may be treated as above, provided *I* is the angle between initial and terminal tangents and *p* as before.

EXAMPLE.—A located 2° 30′ curve, having $I = 25°$, ends in a tangent 25 ft. outside of desired tangent. Find the change in position of *P.C.*

By (52), $AC = 25 \times 2.36620 = 59.16$ ft.

### 112. To Find the Change in Radius and Position of *P.C.* if *P.T.* is Required to fall on the same Radial Line but on a Tangent distant *p* from, and parallel to, Terminal Tangent to Located Curve.

In Fig. 37 let $AB$ be the located and $CE$ the required curve. Draw the parallel chords $AB$ and $CE$. Draw $CH$ and $BF$ perpendicular to $AB$. The angles $FBE = CAH = \frac{1}{2}I$.

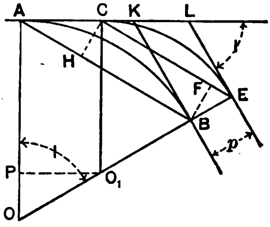


FIG. 37.

From the figure,

$$CH = AC \sin \tfrac{1}{2}I,$$

$$BF = BE \cos \tfrac{1}{2}I = p \cos \tfrac{1}{2}I.$$

Equating,

$$AC \sin \tfrac{1}{2}I = p \cos \tfrac{1}{2}I,$$

whence

$$AC = p \cot \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (53)$$

In the triangle $OPO_1$, $O_1P = AC$, $OP = R - R_1$, and

$$(R - R_1) \tan I = AC = p \cot \tfrac{1}{2}I,$$

or $$R - R_1 = AC \cot I = p \cot \tfrac{1}{2}I \,.\, \cot I.$$

Therefore

$$R_1 = R - AC \cot I = R - p \cot \tfrac{1}{2}I \,.\, \cot I. \quad . \quad . \quad (54)$$

From trigonometry,

$$\cot \tfrac{1}{2}I = \frac{\sin I}{1 - \cos I} \quad \text{and} \quad \cot I = \frac{\cos I}{\sin I}.$$

Inserting these values in (54) gives

$$R_1 = R - p \,.\, \frac{\sin I}{1 - \cos I} \cdot \frac{\cos I}{\sin I} = R - p \frac{\cos I}{1 - \cos I} = R - p \frac{\cos I}{\text{vers } I}.$$

From trigonometry, $$\text{ex sec } I = \frac{\text{vers } I}{\cos I}.$$

$$\therefore R_1 = R - \frac{p}{\text{ex sec } I}. \quad . \quad . \quad . \quad . \quad . \quad (54')$$

EXAMPLE.—A 2° 30′ curve strikes 25 ft. inside a tangent in which the *P.T.* must fall. Find the necessary change in radius and position of *P.C.* when $I = 25°$.

By (53) the change in *P.C.* is

$$AC = 25 \times 4.51071 = 112.77 \text{ ft.}$$

By (54′), $$R_1 = 2292.01 - \frac{25}{.10338} = 2050.38 \text{ ft.}$$

By Table I we find this to be the radius of a 2° 47′ 41″ curve.

### 113. Given a Located Curve uniting Two Tangents to Find the Change in Position of *P.C.* or in Radius for a Given Change in the Intersection-angle.

FIRST CASE.—*Radius unchanged.*

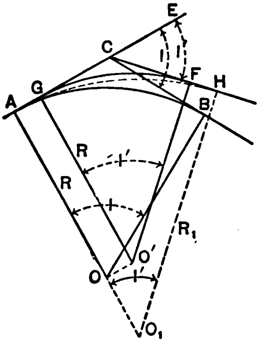


FIG. 38.

In Fig. 38 let $BCE = I$ be the original intersection-angle, $FCE = I'$ the new angle. From the figure,

$$AG = AC - GC,$$

or

$$AG = R\,(\tan \tfrac{1}{2}I - \tan \tfrac{1}{2}I'). \quad (55)$$

BY TABLE IX.—From the table, for angle $I$,

$$T = \frac{T_1 \measuredangle I^\circ}{D}$$

For $I'$

$$T' = \frac{T_1 \cdot \measuredangle I'^\circ}{D}.$$

Then $$AG = T - T'.$$

SECOND CASE.—*P.C. unchanged.*

Here the tangent $T'$ for the two curves is the same, and therefore

$$R_1 \tan \tfrac{1}{2}I' = R \tan \tfrac{1}{2}I;$$

Whence $$R_1 = R \tan \tfrac{1}{2}I \,.\, \cot \tfrac{1}{2}I'. \quad . \quad . \quad . \quad . \quad (56)$$

By Table IX,

$$T = \frac{T_1 \measuredangle I^\circ}{D} = \frac{T_1 \measuredangle I'^\circ}{D_1},$$

whence
$$D_1 = \frac{T_1 \measuredangle I'^\circ}{T_1 \measuredangle I^\circ} \cdot D = \frac{T_1 \measuredangle I'^\circ}{T}.$$

### 114. To Find the Change in *R* and *P.C.* for a Given Change in *I*, the *P.T.* remaining unchanged

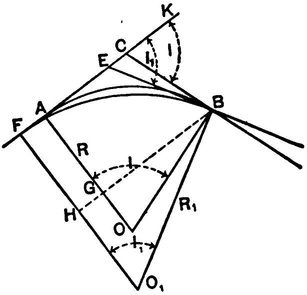


Fig. 39.

In Fig. 39, from the triangles $OBG$ and $O_1BH$,

$$OG = R \cos I$$

and
$$O_1H = R_1 \cos I_1.$$

Now $GA = HF$; hence

$$R_1 - R_1 \cos I_1 = R - R \cos I.$$

Whence

$$R_1 = R\frac{1 - \cos I}{1 - \cos I_1} = R\frac{\text{vers } I}{\text{vers } I_1}. \quad . \quad . \quad . \quad . \quad . \quad (57)$$

Also, $FA = HG = BH - BG.$

Inserting values of $BH$ and $BG$, there results

$$FA = R_1 \sin I_1 - R \sin I. \quad . \quad . \quad . \quad . \quad . \quad (58)$$

### 115. Given a Located Curve to Find the Change in *R* for a Given Change in *T*, *I* remaining unchanged.

In Fig. 40, from the triangles $OAC$ and $O_1EC$, since $EA = EC - AC$,

$$R_1 \tan \tfrac{1}{2}I - R \tan \tfrac{1}{2}I = EA = T' - T.$$

Whence $$R_1 = R + (T' - T) \cot \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \qquad (59)$$

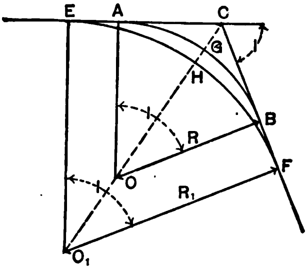


FIG. 40.

BY TABLE IX.—$EA$ being known, $T' = T + EA$. Then, by (15$a$),

$$D_1 = \frac{T_1 \measuredangle I^\circ}{T'}.$$

If the change in vertex of curve is wanted, there results, from (25),

$$E = CG = T \tan \tfrac{1}{4}I, \qquad E' = CH = T' \tan \tfrac{1}{4}I.$$

Therefore $$GH = E' - E = (T' - T) \tan \tfrac{1}{4}I. \quad . \quad . \quad . \qquad (60)$$

$GH$ can be found from Table IX after finding $D_1$ as above.

If $R_1$ is given and $EA$ wanted, (59) yields

$$EA = T' - T = (R_1 - R) \tan \tfrac{1}{2}I.$$

**116. To Find the Radius of a Curve having the Same *P.C.* as a Given Curve, but ending in a Parallel Tangent.**

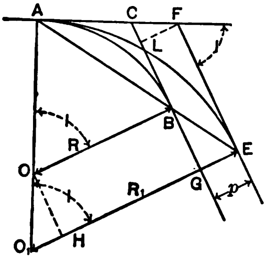


FIG. 41.

In Fig. 41 let the perpendicular distance between tangents be $p$, and $AB$ be the located curve; $AO_1 = R_1$ is required.

FIRST METHOD.—Draw $OH$ at right angles to $O_1E$; then

$$O_1E = O_1H + HG + GE,$$

or

$$R_1 = (R_1 - R) \cos I + R + p.$$

From which $$R_1 = R + \frac{p}{1 - \cos I} = R + \frac{p}{\operatorname{vers} I}. \quad . \quad . \quad . \qquad (61)$$

SECOND METHOD.—$A$, $B$, and $E$ lie on the same straight line, since $I$ is the same for both curves. In triangle $BGE$ angle $EBG = \frac{1}{2}I$, and

$$BE = \frac{p}{\sin \frac{1}{2}I} = p \operatorname{cosec} \tfrac{1}{2}I.$$

From Table IX, $AB = \dfrac{L.C._1 \measuredangle I^\circ}{D}$.

$AE = AB + BE$ is the long chord for curve of degree $D_1$; therefore

$$D_1 = \frac{L.C._1 \measuredangle I^\circ}{AE}.$$

If desired, $R$ may be found by (12′) or Table I.

THIRD METHOD.—Draw $FL$ parallel to $O_1E$; then

$$CF = \frac{p}{\sin I} = p \operatorname{cosec} I.$$

From Table IX, $AC = \dfrac{T_1 \measuredangle I^\circ}{D}$.

$AF = AC + CF$, the tangent distance for second curve; hence

$$D_1 = \frac{T_1 \measuredangle I^\circ}{AF}.$$

REMARK.—If transit is set up at $B$, it will be well to set $E$ by measurement from $B$, to serve as a check when the curve is run in from $A$.

## ARTICLE 9. COMPOUND CURVES.

### *A. Location Problems.*

**117. Given Two Unequal Tangents, their Intersection-angle, and One Radius, to Find the Other Radius of a Compound Curve uniting Tangents.**

In Fig. 42, $AH = T_1$ and $BH = T_2$ are the known tangents, $AO_1 = R_1$ the known radius. $BO_2 = R_2$ and the angles $I_1$ and $I_2$ must be found before curve can be located.

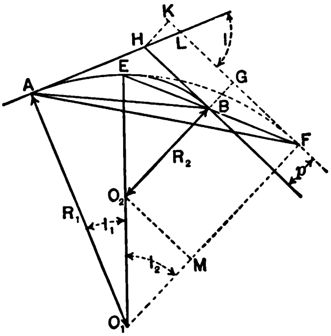


FIG. 42.

Extend first branch to $F$, so that tangent $FL$ is parallel to $BH$. Draw $HK$ and $BG$ perpendicular to $FL$; draw $FB$ and extend to $E$; it will pass through the $P.C.C.$, because the central angles $EO_1F$ and $EO_2B$ are equal. Then

$$T_0 = AL = R_1 \tan \tfrac{1}{2}I.$$

In triangle $LHK$, since $LH = T_0 - T_1$,

$$s = KL = (T_0 - T_1)\cos I,$$

$$p = HK = BG = (T_0 - T_1)\sin I.$$

Now in triangle $BGF$ angle $BFG = \tfrac{1}{2}I_2$, and

$$l = FG = T_0 + s - T_2,$$

$$\tan \tfrac{1}{2} I_2 = \frac{p}{l} . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (62)$$

Draw $O_2M$ parallel to $FL$; then

$$(R_1 - R_2) \sin I_2 = l,$$

whence

$$R_2 = R_1 - \frac{l}{\sin I_2} = R_1 - l \operatorname{cosec} I_2. \quad . \quad . \qquad (63)$$

Had $R_1$ been required, the equation would have been

$$R_1 = R_2 + l \operatorname{cosec} I_2.$$

Evidently, $\qquad I_1 = I - I_2.$

In the field the points $E$ and $B$ may be located by running in the curve from $A$ as starting-point, or run the chord

$$AF = 2R_1 \sin \tfrac{1}{2} I$$

from $A$, and at $F$ deflect angle $AFB = \frac{1}{2}I - \frac{1}{2}I_2 = \frac{1}{2}I_1$, measure $FB = l \sec \frac{1}{2}I_2$ and $BE = 2R_2 \sin \frac{1}{2}I_2$.

EXAMPLE.—A 2° curve has the *P.C.* at sta. 110, $T_1 = 590$ ft., $T_2 = 511.8$ ft., $I = 30° 50'$. Locate the curve.

By Table IX, $\qquad T_0 = 1580/2 = 790$ ft.

By formulas above,

$$s = 200 \times 0.85866 = 171.73 \text{ ft.},$$

$$p = 200 \times 0.51254 = 102.51 \text{ ft.},$$

$$l = 790 + 171.73 - 511.8 = 449.93,$$

$$\tan \tfrac{1}{2} I_2 = \frac{102.51}{449.93} = 0.22784 = \tan 12° 50'.$$

Then $\qquad I_1 = 30° 50' - 25° 40' = 5° 10'.$

$$R_2 = 2864.93 - \frac{449.97}{.43313} = 1833 \text{ feet.}$$

By Table I this is seen to be the radius of a 3° 7½′ curve.

The length of first branch is 258.3 feet, and of the second 821.3 feet; hence the *P.C.C.* falls at 112 + 58.3, while the *P.T.* is at sta. 120 + 79.6.

### 118. Given the Long Chord from *P.C.* to *P.T.* of a Compound Curve, the Angles it makes with the Tangents and One Radius, to Find the Other Radius and the Central Angles.

In Fig. 42 $AB$ is known, as also the angles $HAB = a$ and $HBA = b$. Two angles and one side of the triangle $HAB$ are known, and the sides $HA = T_1$ and $HB = T_2$ may be found, after which the solution is the same as in the last problem.

A solution may be reached in a different manner. $I = a + b$, $HAF = \frac{1}{2}I = \frac{1}{2}(a + b)$, and $BAF = \frac{1}{2}(a + b) - a = \frac{1}{2}(b - a)$, $AF = 2R_1 \sin \frac{1}{2}I$. In triangle $BAF$ two sides and the included angle are now known, so $BF$ and angle $BFA$ may be found; $GFB = \frac{1}{2}I_2 = \frac{1}{2}I - BFA$.

Then $$EF = 2R_1 \sin \tfrac{1}{2}I_2,$$

and $$EB = EF - BF \text{ becomes known.}$$

Then $$EB = 2R_2 \sin \tfrac{1}{2}I_2 = 2R_1 \sin \tfrac{1}{2}I_2 - BF,$$

whence $$R_2 = R_1 - \frac{BF}{2 \sin \frac{1}{2}I_2}. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (64)$$

Evidently $I_1 = I - I_2$

### 119. Given the Radii and Central Angles of a Compound Curve to Find the Tangent Lengths, the Long Chord from *P.C.* to *P.T.*, and the Angles it makes with Tangents.

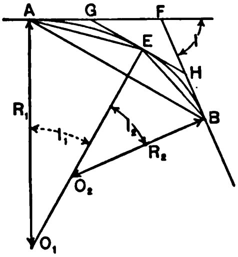


FIG. 43.

In Fig. 43 draw $AE$ and $BE$ from the *P.C.* and *P.T.* to the *P.C.C.*, then calculate $AE$ and $BE$ by (16) or by Table IX. In triangle $AEB$ angle $AEB = 180 - \frac{1}{2}(I_1 + I_2)$. Two sides and the included angle being known, the triangle $AEB$ may be solved for $AB$ and the angles $ABE$ and $BAE$; then

$$BAF = BAE + \tfrac{1}{2}I_1,$$
$$ABF = ABE + \tfrac{1}{2}I_2.$$

The angle $AFB$ of triangle $ABF$ now becomes known and, as

$AB$ is known, the sides $AF = T_1$ and $BF = T_2$ may be computed.

### 120. Given the Long Chord from *P.C.* to *P.T.* of a Compound Curve and the Angles it makes with Tangents to Find the Radii when the Common Tangent is Parallel to Long Chord.

In Fig. 43 let $GH$ be parallel to $AB$, and $GAB = a$, $HBA = b$ known. Then

$$BAE = EAG = GEA = \tfrac{1}{2}a,$$

and
$$ABE = EBH = HEB = \tfrac{1}{2}b.$$

Also,
$$AEB = 180° - \tfrac{1}{2}(a + b).$$

In triangle $AEB$, remembering that

$$\sin\,[180 - \tfrac{1}{2}(a + b)] = \sin \tfrac{1}{2}(a + b),$$

$$AE = \frac{AB \sin \tfrac{1}{2}b}{\sin \tfrac{1}{2}(a + b)},$$

and

$$BE = \frac{AB \sin \tfrac{1}{2}a}{\sin \tfrac{1}{2}(a + b)}.$$

Since $AO_1E = a$ and $EO_2B = b$, the radii $R_1$ and $R_2$ may be found from formula (16), or (16*a*).

By (16),
$$R_1 = \frac{\tfrac{1}{2}AE}{\sin \tfrac{1}{2}a} = \frac{AB \sin \tfrac{1}{2}b}{2 \sin \tfrac{1}{2}a \,.\, \sin \tfrac{1}{2}(a + b)}. \quad . \quad . \quad . \quad (65)$$

$$R_2 = \frac{\tfrac{1}{2}BE}{\sin \tfrac{1}{2}b} = \frac{AB \sin \tfrac{1}{2}a}{2 \sin \tfrac{1}{2}b \,.\, \sin \tfrac{1}{2}(a + b)}. \quad . \quad . \quad . \quad (66)$$

Example.—Required $R_1$ and $R_2$, or $D_1$ and $D_2$, when $AB = 900$ feet, $a = 12°$, $b = 15°$.

By (65), $R_1 = 2407.0$ ft.

By (66), $R_2 = 1543.7$ ft.

From Table I, $D_1 = 2° \, 22' \, 50''$ and $D_2 = 3° \, 42' \, 44''$.

## *B. Obstacles.*

### **121. To Locate a Point on the Second Branch of a Compound Curve when the *P.C.C.* is Inaccessible.**

Ordinarily the second branch is located by setting transit at the *P.C.C* and running the curve from that point. An obstacle on either curve may then be passed by the methods given for simple curves.

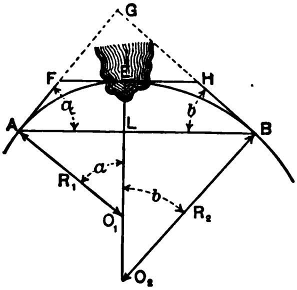


FIG. 44.

When the *P.C.C.* is inaccessible, locate the first branch from the *P.C.* and the second branch from the *P.T.*, if this latter point is known. When this is not the case proceed by one of the following methods:

FIRST. *By means of a long chord.*

In Fig. 44 let *E* be the *P.C.C.*, *A* some known point on first branch, *EF* a tangent at *E*, and *AB* parallel to *FE*. The station numbers of *A* and *E* being known, the arc *AE* and angle *a* are readily found; then

$$EL = R_2 \text{ vers } b = R_1 \text{ vers } a,$$

whence

$$\text{vers } b = \frac{R_1 \text{ vers } a}{R_2}; \quad \ldots\ldots\ldots\ldots \quad (67)$$

next,

$$AB = R_1 \sin a + R_2 \sin b. \quad \ldots\ldots \quad (68)$$

Deflect $FAB = a$ from tangent at $A$; measure out $AB$; set the transit at $B$ and locate the second branch.

BY TABLE IX.—Take the mid-ordinate in table for an intersection-angle $2a$; then

$$EL = \frac{M_1 \measuredangle 2a}{D_1}.$$

Then $EL \times D_2$ is the mid-ordinate for a 1° curve having $I = 2b$, from which $b$ becomes known. From the table now find $AL$ and $LB$, the half-chords for angles $2a$ and $2b$, and proceed as before.

SECOND METHOD.—*By means of tangents.*

From Fig. 44, $AF = FE = R_1 \tan \frac{1}{2}a$.

Set transit at $F$, deflect $GFE = a$, and by some indirect method measure to an accessible point $H$.

$$EH = FH - FE,$$

and

$$\tan \tfrac{1}{2}b = \frac{EH}{R_2}, \text{ from formula (14).}$$

Angle $b$ is now known and equals $GHE$, which deflect from $EH$; then measure $HB = EH$, and with transit at $B$ locate the second branch of curve.

Or by Table IX.—Find $AF = FE$, the tangent distance for $I = a$; then having $EH$ measured, take $T_1 = EH \times D_2$ and find the corresponding angle, which equals $b$; then proceed to locate curve as above.

Example.—Let $A$ be at sta. 126, $P.C.C.$ at 128 + 25; the degree of first branch 4°, and of second 6°.

By the first method $EL = 17.635$ for $a = 9°$, and $b = 11° 2'$, nearly. $AL \doteq 224.1$ ft., $BL = 182.75$ ft., and therefore $AB = 406.85$ ft. Angle $b = 11° 2'$ corresponds to 183.9 ft. around 6° curve; hence the $P.T.$ number is 130 + 08.9.

By the second method $AF = 112.74$ ft. Suppose $FH = 264$ ft., then $EH = 151.26$ ft., which multiplied by 6 gives 907.56 ft., corresponding to $I = 18°$. The arc $EB$ is now 300 ft., making $B$ fall at sta. 131 + 25.

## *C. Change of Location.*

### 122. Having a Simple Curve Located to Find the $P.C.C.$ so that a Curve of Given Radius shall connect with a Given Tangent Parallel to Tangent to Located Curve.

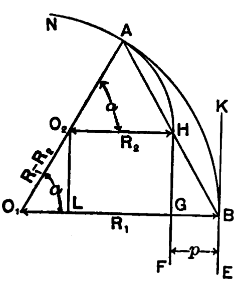


Fig. 45.

Let $NAB$, Fig. 45, be the located curve, $HF$ the tangent in which the second branch must end. The distance $BG = p$ between tangents is known from measurement. If angle $a$ can be found, the arc $BA$ becomes known and the point $A$ can be located from $B$. Draw $O_2L$ from the center of second branch perpendicular to $O_1B$. In triangle $O_1O_2L$, $O_1O_2 = R_1 - R_2$, and $O_1L = R_1 - (R_2 + p)$; therefore

$$\cos a = \frac{R_1 - R_2 - p}{R_1 - R_2} = 1 - \frac{p}{R_1 - R_2}. \quad . \quad . \quad (69)$$

Then $a$ divided by $D_1$ gives arc $BA$.

If desired, $BH$ may be found from the right triangle $BHG$, in which the side $BG = p$ and angle $GHB = \frac{1}{2}a$ are known—$A$, $H$, and $B$ lying in the same straight line; then

$$BH = \frac{p}{\sin \frac{1}{2}a} = p \operatorname{cosec} \tfrac{1}{2}a. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (70)$$

Or $BA$ and $HA$ may be found from Table IX, after which

$$BH = BA - HA.$$

Example.—A 3° curve ends in a tangent at sta. 160 + 50, 35 ft. outside of desired tangent. Find the point of compounding with a 4° 50′ curve.

From Table I, $R$ for 3° curve equals 1910.08 ft., and for 4° 50′ curve 1185.78 ft.

Then, by (69), $\cos a = 1 - \frac{35}{724.3} = 0.95168.$

From table of cosines angle $a$ is found to be 17° 53′. Dividing this by 3 gives 5.961 stations for the arc $BA$. Hence the *P.C.C.* number is 160.50 − 5.961 = sta. 154 + 53.9, and the new *P.T.* is at sta. 158 + 23.9.

### 123. Given a Located Compound Curve ending in a Tangent Parallel to, and a Given Distance from, a Tangent in which the Curve is required to end. To Find the Necessary Change in *P.C.C.*

First Case.—*Terminal branch having shorter radius.*

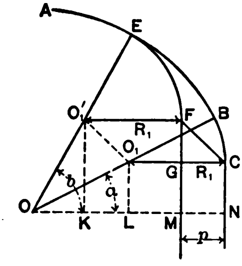


Fig. 46.

In Fig. 46 let $ABC$ be the located curve, $AEF$ the one required; angle $BO_1C = a$ known, and also $MN = p$.

If angle $EOM = b$ can be found, the angle of retreat from $B$ to $E$ will equal $b - a$.

Draw $O_1'K$ and $O_1L$ perpendicular to $ON$, which is parallel to $O_1C$.

Then $OK = (R - R_1) \cos b$,

$OL = (R - R_1) \cos a$.

Now $LM = R_1 - KL = R_1 - MN$, from which $KL = MN = p$. Hence

$$(R - R_1) \cos b = (R - R_1) \cos a - p.$$

From which

$$\cos b = \cos a - \frac{p}{R - R_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (71)$$

Divide $b - a$ by $D$, the curvature of first branch, and move back that number of stations from $B$ to the new $P.C.C.$ at $E$.

Join $O.O_1'$; evidently $FC = O_1O_1'$, and angle $KO_1'O_1 = CFG$; $OO_1'O_1 = 90° - \frac{1}{2}(b - a)$, $OO_1'K = 90° - b$. Hence

$$CFG = KO_1'O_1 = [90 - \tfrac{1}{2}(b - a)] - (90 - b) = \tfrac{1}{2}(b + a). \quad (72)$$

From triangle $CGF$,

$$FC = \frac{p}{\sin \frac{1}{2}(b + a)} = p \operatorname{cosec} \tfrac{1}{2}(b + a). \quad . \quad . \quad (73)$$

Or, from triangle $OO_1'O_1$,

$$FC = O_1'O_1 = 2(R - R_1) \sin \tfrac{1}{2}(b - a).$$

Had $AEF$ been the original curve, $b$ would have been known and $a$ required.

From (71), $$\cos a = \cos b + \frac{p}{R - R_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (74)$$

$CF$ and angle $CFM$ are given by formulas (73) and (72).

Example.—A 2° curve compounds with a 4° curve at sta. 82 + 30; $a = 20° 30'$, $p = 40$ feet. Find number of new $P.C.C.$ and distance between $P.T.$s.

From (71), $$\cos b = 0.93667 - \frac{40}{2864.9 - 1432.7} = 0.90874.$$

This yields $b = 24° 40'$, and $b - a = 4° 10'$.

The change in $P.C.C.$ is $\frac{4.166}{2} = 2.083$ stations; the $P.C.C.$ number is therefore $82.30 - 2.083 =$ sta. $80 + 21.7$.

By (72), $CFG = \frac{1}{2}(24° 40' + 20° 30') = 22° 35'$.

By (73), $FC = 40 \times 2.60399 = 104.2$ feet.

SECOND CASE.—*The terminal branch having longer radius.*

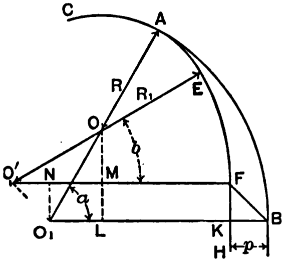


FIG. 47.

Let $CAB$, Fig. 47, be the located curve with $P.C.C.$ at $A$, and let $FK$ be the tangent in which the curve is required to end.

The distance $BK = p$, the radii $OA = R$, $O_1A = R_1$, and angle $AO_1B = a$ being known, it will be sufficient to find angle $EO_1'F$ in order to get the angle of advance, $AOE = a - b$. Draw $OL$ and $O_1N$ perpendicular to $O_1'F$ and $O_1B$. From the triangles $O_1'OM$ and $O_1OL$,

$$(R_1 - R) \cos b = O_1'N + (R_1 - R) \cos a.$$

But $O_1'N = KB = p$; therefore

$$(R_1 - R) \cos b = p + (R_1 - R) \cos a.$$

Whence
$$\cos b = \cos a + \frac{p}{R_1 - R}. \quad . \quad . \quad . \quad . \quad (75)$$

Then $\frac{a - b}{D}$ will be length of curve from $A$ to $E$.

$$\text{Angle } KFB = NO_1O_1' = OO_1O_1' - NO_1O.$$

But $OO_1O_1' = 90° - \frac{1}{2}(a - b)$ and $NO_1O = 90 - a$.

$$\therefore \; KFB = [90° - \tfrac{1}{2}(a - b)] - [90 - a] = \tfrac{1}{2}(a + b).$$

From triangle $KFB$,

$$FB = \frac{p}{\sin \frac{1}{2}(a + b)} = p \,.\, \text{cosec} \tfrac{1}{2}(a + b). \quad . \quad . \quad . \quad (76)$$

Or, from triangle $O_1OO_1'$, since $O_1O_1' = FB$,

$$FB = 2(R_1 - R) \sin \tfrac{1}{2}(a - b).$$

If $AEF$ had been the located curve, $b$ would have been given and $a$ required. From formula (75),

$$\cos a = \cos b - \frac{p}{R_1 - R}. \quad . \quad . \quad . \quad . \quad . \quad (77)$$

EXAMPLE.—A 5° curve compounds at sta. 60 with a 2° curve, and the $P.T.$ is at sta. 80. What will be the number of $P.C.C.$ if the $P.T.$ fall in a tangent 81 feet inside of terminal tangent? Here $a = 40°$.

By (75), $$\cos b = 0.76604 + \frac{81}{1719} = 0.81316.$$

Hence $b = 35° \, 36'$ and $a - b = 4° \, 24'$, corresponding to 88 feet around the 5° curve. The number of the new $P.C.C.$ is therefore 60 + 88.

$$\text{angle } KFB = \tfrac{1}{2}(40° \, 0' + 35° \, 36') = 37° \, 48',$$

and $$FB = 81 \times 1.63157 = 132.16 \text{ feet.}$$

### 124. Given a Located Compound Curve to Find Necessary Change in *P.C.C.* and Radius of Second Branch to make the *P.T.* fall in a Tangent Parallel to First Terminal Tangent and in a Point on the Same Radial Line.

FIRST CASE.—*Second branch having shorter radius.*

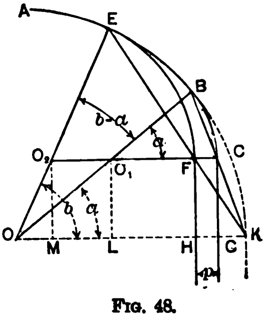


FIG. 48.

In Fig. 48, $OB = R$, $O_1B = R_1$ angle $a$ and $HG = p$ are known. $O_2E = R_2$ and angle $b$ must be found; then $\frac{b-a}{D} = BE$ will be the change in $P.C.C.$

Produce first branch to $K$, where $OK$ is parallel to $O_1C$. Since $BOK = BO_1C$, $B$, $K$, and $C$ lie in the same straight line; and since $EO_2F = EOK$, $E$, $F$, and $K$ lie in the same straight line. Therefore

$$KCG = \tfrac{1}{2}a, \quad \text{and} \quad KFH = \tfrac{1}{2}b.$$

From triangles $KFH$ and $KCG$,

$$\tan \tfrac{1}{2}b = \frac{HK}{FH} = \frac{GK}{GC} + \frac{GH}{FH} = \tan \tfrac{1}{2}a + \frac{p}{FH}$$

But $FH = O_1L = (R - R_1) \sin a.$

$$\therefore \quad \tan \tfrac{1}{2}b = \tan \tfrac{1}{2}a + \frac{p}{(R - R_1) \sin a}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (78)$$

From triangles $OO_1L$ and $OO_2M$,

$$(R - R_2) \sin b = (R - R_1) \sin a.$$

Whence $$R_2 = R - (R - R_1) \frac{\sin a}{\sin b}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (79)$$

Had $AEF$ been the first curve located, $b$ and $R_2$ would be known, $a$ and $R_1$ required.

From the figure, reasoning as before,

$$\tan \tfrac{1}{2}a = \tan \tfrac{1}{2}b - \frac{p}{(R - R_2) \sin b}, \quad . \quad . \quad . \quad . \quad (80)$$

and

$$R_1 = R - (R - R_2) \frac{\sin b}{\sin a}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (81)$$

SECOND CASE.—*Second branch having longer radius.*

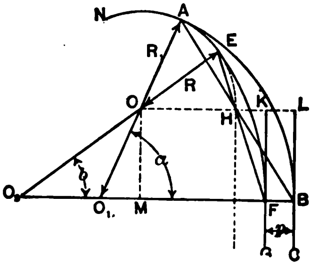


FIG. 49.

In Fig. 49 let $AB$ be the located curve, $EF$ the curve required, $OA = R$, $O_1A = R_1$, $O_2E = R_2$, $FB = p$.

$R_2$ and angle $b$ are wanted, angle $a$ being known.

We can show, as in first case, that

$$HFK = \tfrac{1}{2}b, \quad HBL = \tfrac{1}{2}a,$$

$$OM = KF = LB = (R_1 - R)\sin a;$$

and hence

$$\tan \tfrac{1}{2}b = \frac{HK}{FK} = \frac{HL}{BL} - \frac{p}{BL}.$$

Or inserting values,

$$\tan \tfrac{1}{2}b = \tan \tfrac{1}{2}a - \frac{p}{(R_1 - R)\sin a}. \quad . \quad . \quad . \quad . \quad . \quad (82)$$

Angle $b$ now becomes known and $\frac{a-b}{D} = AE$ in chains, which is the change in position of $P.C.C.$

From triangles $OO_1M$ and $OO_2M$,

$$(R_2 - R)\sin b = (R_1 - R)\sin a$$

$$\therefore\ R_2 = R + (R_1 - R)\frac{\sin a}{\sin b}. \quad . \quad . \quad . \quad . \quad . \quad (83)$$

Had the new tangent fallen outside the old one, we should have had

$$\tan \tfrac{1}{2}a = \tan \tfrac{1}{2}b + \frac{p}{(R_2 - R)\sin b}, \quad . \quad . \quad . \quad (84)$$

and

$$R_1 = R + (R_2 - R)\frac{\sin b}{\sin a}. \quad . \quad . \quad . \quad . \quad . \quad (85)$$

**125. Having a Located Compound Curve, to Find the Change in $P.C.C.$ and Radius of Second Branch in order to Cause $P.T.$ to Fall at a New Point in Terminal Tangent.**

**First Case.**—*Second branch having shorter radius.*

In Fig. 50 let $NAB$ be the located curve, and $C$ the point where $P.T.$ is required to fall. Let $BC = k$, $OA = R$, $O_1B = R_1$, and angle $O_1OH = a$ be known; angle $b$ and $R_2$ are required.

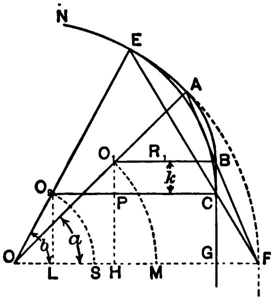


FIG. 50.

Extend first branch to $F$, making $OF$ parallel to $O_1B$. $A$, $B$, and $F$ lie on a straight line, for angles $AO_1B$ and $AOF$ are equal; likewise $E$, $C$, and $F$ lie on the same straight line.

From triangles $GBF$ and $GCF$,

$$\cot \tfrac{1}{2}b = \frac{GB}{GF} - \frac{CB}{GF} = \cot \tfrac{1}{2}a - \frac{k}{GF}$$

But $GF = HM = (R - R_1)(1 - \cos a) = (R - R_1) \text{ vers } a$.

$$\therefore\ \cot \tfrac{1}{2}b = \cot \tfrac{1}{2}a - \frac{k}{(R - R_1) \text{ vers } a}. \quad . \quad . \quad . \quad . \quad (86)$$

From triangles $OO_1H$ and $OO_2L$, since $O_1P = k$,

$$(R - R_2) \sin b = (R - R_1) \sin a - k.$$

Whence

$$R_2 = R + \frac{k - (R - R_1) \sin a}{\sin b}. \quad . \quad . \quad . \quad . \quad (87)$$

Then $b - a$ divided by $D$ gives arc $AE$. With radius $R_2$ locate the curve $EC$ from $C$ or $E$.

Had *NEC* been the located curve, $R$, $R_2$, and $b$ would have been known, $R_1$ and $a$ required. In this case

$$\cot \tfrac{1}{2}a = \cot \tfrac{1}{2}b + \frac{k}{(R - R_2)\operatorname{vers} b}, \quad . \quad . \quad . \quad . \quad (88)$$

$$R_1 = R - \frac{k + (R - R_2)\sin b}{\sin a}. \quad . \quad . \quad . \quad . \quad (89)$$

SECOND CASE.—*Terminal branch having longer radius* In Fig. 51 let *NAB* be the located and *NEC* the required curve.

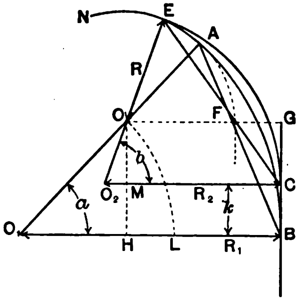


FIG. 51.

Let $CB = k$ be known. Then, as in the first case,

$$\cot \tfrac{1}{2}b = \frac{GC}{FG} = \frac{GB}{FG} - \frac{k}{FG}.$$

$$\therefore \quad \cot \tfrac{1}{2}b = \cot \tfrac{1}{2}a - \frac{k}{(R_1 - R)\operatorname{vers} a}, \quad . \quad . \quad (90)$$

and $$(R_1 - R)\sin a = (R_2 - R)\sin b + k;$$

whence $$R_2 = R + \frac{(R_1 - R)\sin a - k}{\sin b}. \quad . \quad . \quad (91)$$

Had *NEC* been located and *NAB* required, the equations would have been

$$\cot \tfrac{1}{2}a = \cot \tfrac{1}{2}b + \frac{k}{(R_2 - R)\operatorname{vers} b}, \quad . \quad . \quad (92)$$

and

$$R_1 = R + \frac{(R_2 - R)\sin b + k}{\sin a}. \quad . \quad . \quad (93)$$

In either of these two cases if $k$ is unknown and the new radius given or assumed, the desired angle and the value of $k$ may be found from the foregoing equations. Or, knowing the new angle, the new radius and value of $k$ may be found from the same equations.

### 126. To Replace a Curve of Given Radius, which unites Two Tangents with Known Intersection-angle, by a Three-centered Compound Curve.

In Fig. 52 let $OA = R$ be the radius of located curve,

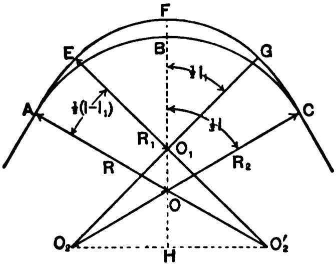


FIG. 52.

$O_2C = O_2'A = R_2$ the radius of terminal portions of the three-centered curve, and the other notation as shown in the figure.

Draw $O_2O_2'$, and draw *FOH* perpendicular thereto. From triangles $O_2O_1H$ and $O_2OH$,

$$O_2H = (R_2 - R_1)\sin \tfrac{1}{2}I_1 = (R_2 - R)\sin \tfrac{1}{2}I. \quad . \quad . \quad . \quad (a)$$

Suppose $R_2$ and $R_1$ to be assumed; then equation (*a*) yields

$$\sin \tfrac{1}{2}I_1 = \frac{R_2 - R}{R_2 - R_1}\sin \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad (94)$$

Then $$AO_2'E = CO_2G = \tfrac{1}{2}(I - I_1). \quad . \quad . \quad . \quad (95)$$

Suppose $AO_2'E$, $CO_2G$, and $R_2$ to have been assumed. From (95) find $I_1$; then, from equation ($a$),

$$R_1 = R_2 - (R_2 - R)\frac{\sin \tfrac{1}{2}I}{\sin \tfrac{1}{2}I_1}. \quad . \quad . \quad . \quad . \quad . \quad (96)$$

EXAMPLE.—Given a 4° curve, $I = 38°$, and the terminal branches composed of a 2° curve for two stations, to find $R_1$ and $D_1$ for the central portion.

Here $$I_1 = 38° - 2(2 \times 2)° = 30°.$$

From Table I, $R_2 = 2865$ ft., $R = 1432.7$ ft.

Whence $$R_2 - R = 1432.3 \text{ ft.}$$

$$\begin{aligned} \text{Log } 1432.3 \quad &= 3.15603 \\ \text{“} \quad \sin 19°\ 0' &= 9.51264 \\ \hline &\phantom{=}\ 2.66867 \\ \text{“} \quad \sin 15°\ 0' &= 9.41300 \\ \hline \therefore \quad \log 1801.7 &= 3.25567 \end{aligned}$$

Therefore $R_1 = 2865 - 1801.7 = 1063.3$ ft., and, by Table I,

$$D_1 = 5°\ 23'.4, \text{ nearly enough.}$$

### 127. To Substitute a Curve of Given Radius for a Tangent uniting Two Curves.

In Fig. 53 let the tangent $BC = t$, $OB = R$, $O_1C = R_1$, and $O_2A = R_2$ be known.

Angles $a$, $b$, and $c$ must be found in order to substitute curve $AE$ for the system $ABCE$.

Draw $OF$ parallel to $BC$, then $O_1F = R_1 - R$, and, from triangle $OO_1F$,

$$\tan d = \frac{t}{R_1 - R}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (97)$$

$$OO_1 = \frac{t}{\sin d} = t \,.\, \operatorname{cosec} d = \sqrt{(R_1 - R)^2 + t^2}. \quad . \quad (98)$$

Now in triangle $OO_1O_2$ three sides are known and the angles $c$ and $e$ may be computed. Thus if $s$ is the half-sum of the sides,

$$\cos \tfrac{1}{2}c = \sqrt{\frac{s(s - OO_1)}{OO_2 \times O_2O_1}}.$$

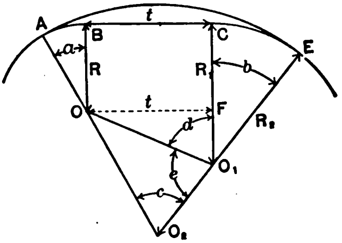


FIG. 53.

Angle $e$ may be found in like manner, then $b = 180° - (e + d)$, and $a = c - b$.

Points $A$ and $E$ may now be located and the curve traced.

EXAMPLE.—A 3° and a 5° curve are united by a tangent 500 feet long. Replace by a 2° curve.

Here $R_1 - R = 1910 - 1146 = 764$ feet.

By (97), $\tan d = \dfrac{500}{764} = 0.65444 = \tan 33° 12'$

By (98), $OO_1 = 913.1$ feet.

In triangle $OO_1O_2$, $OO_1 = 913.1$, $O_1O_2 = 954.9$, and $OO_2 = 1718.7$ feet. Solving for $e$ and $c$,

$e = 133° 36'$. $c = 23° 0'$. Then $b = 13° 12'$, $a = 9° 48'$.

### ARTICLE 10.—TRACK PROBLEMS—CURVED FROGS ASSUMED.

**128. Reversed Curves** should never be employed on main lines because of the shock due to sudden reversal of curvature and superelevation of outside rail. A short tangent should be interposed between the two curves, which may ordinarily be done by changing the end-points of the curve, or slightly altering the radius. At least one large railway system in the United States prescribes 120 feet as the minimum length of intervening tangent. If, however, transition curves are employed to ease off both curves, there would seem to be less objection to the use of curves of contrary flexure, provided the track may be kept always in perfect condition. In yards, crossovers, and where connection is made with existing track, reversed curves may be employed, and are often imperative.

### 129. Having a Located Curve Intersected by a Straight Line, to Connect them by Another Curve.

Either the radius of the joining curve may be given, or else the point on first curve at which the junction must be made. The angle between a tangent to located curve at the point of meeting and the straight line must be measured. Four possible cases occur.

FIRST CASE.—*Joining curve tangent to located curve internally and on same side of cutting line as center.*

In Fig. 54 let $GF$ be joining curve, with center $O_1$ and radius $R_1$. Let radius of located curve $OF = R$. Draw $O_1G$ and $OH$ perpendicular to the cutting line produced, and $O_1K$ parallel to $AH$. If $R_1$ is known, we must determine angle $b$, $a$ having been measured; then $b - a$ gives the length of arc from $A$ to $F$ where the $P.C.C.$ is to be located. In the triangle $KOO_1$ we have

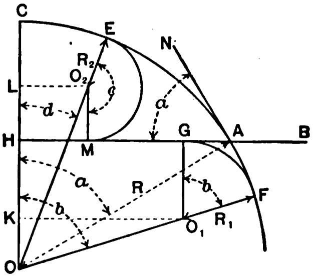


FIG. 54.

$$OK = OH - R_1 \quad \text{and} \quad OO_1 = R - R_1.$$

$$\therefore \quad \cos b = \frac{R \cos a - R_1}{R - R_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (99)$$

Then $$\frac{b - a}{D} = \text{arc } AF.$$

Had $F$ been given, we should have $b = a + AOF$, and, from (99),

$$R_1 = \frac{R (\cos a - \cos b)}{1 - \cos b} = \frac{R (\cos a - \cos b)}{\text{vers } b}. \quad (100)$$

EXAMPLE.—A 1° curve is cut by a tangent that makes an angle of 64° 32′ with tangent to curve. Unite by means of a 4° curve.

By (99), $\cos b = 0.24000 = \cos 76° \; 07'$, and therefore $b - a =$ 11° 35′, making $AF$, of figure, 11.58 stations.

SECOND CASE. — *Joining curve tangent internally to located curve but on opposite side of cutting line from center of located curve.*

In Fig. 54 let arc $ME$, with center $O_2$ and radius $R_2$, be the joining curve. From the figure,

$$\cos d = \frac{R \cos a + R_2}{R - R_2}. \quad . \quad . \quad . \quad . \quad . \quad (101)$$

Then arc $AE = a - d$ divided by $D$, and $c = 180° - d$.

Had the point $E$ been given and $R_2$ required, it would have been, from (101)

$$R_2 = \frac{R(\cos d - \cos a)}{1 + \cos d}. \quad . \quad . \quad . \quad . \quad . \quad (102)$$

EXAMPLE.—Take the same example as in first case. Here,

By (101), $\cos d = 0.9068 = \cos 24° \; 56'$.

Then $64° \; 32' - 24° \; 56' = 39° \; 36'$,

equivalent to 39.600 stations around curve from $A$ to $E$.

THIRD CASE.—*Joining curve tangent externally to located curve, with center on same side of cutting line.*

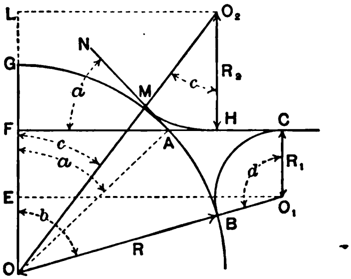


FIG. 55.

In Fig. 55 let arc $BC$, with center $O_1$ and radius $R_1$, be the joining curve. Draw $O_1E$ parallel to $CF$, and $O_1C$ and $OF$ perpendicular thereto.

From the figure,

$$(R + R_1) \cos b = R \cos a - R_1;$$

$$\therefore \cos b = \frac{R \cos a - R_1}{R + R_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (103)$$

Then $d = 180 - b$, and $AOB = b - a$. The curve may now be traced on the ground.

If $AC$ is wanted, we have $AC = (R + R_1) \sin b - R \sin a$.

If the point $B$ is fixed and $R_1$ required, there results, from (103),

$$R_1 = \frac{R (\cos a - \cos b)}{1 + \cos b} \quad . \quad . \quad . \quad . \quad . \quad . \quad (104)$$

**Example.**—Take the example given for the first and second cases.

By (103),

$$\cos b = \frac{5730 \times 0.43 - 1432.5}{5730 + 1432.5} = 0.144 = \cos 81° \, 44'$$

$b - a = 81° \, 44' - 64° \, 32' = 17° \, 12'$, equivalent to 17.2 stations on located curve from $A$ to $B$. Angle $d = 180° - 81° \, 44' = 98° \, 16'$, equivalent to 24.567 stations from $B$ to $C$ on the 4° curve.

**Fourth Case.**—*Joining curve tangent externally to located curve, with center on opposite side of cutting line.*

Let $O_2$, Fig 55, be center of joining curve, $R_2$ its radius. From the figure,

$$(R + R_2) \cos c = R \cos a + R_2.$$

$$\therefore \cos c = \frac{R \cos a + R_2}{R + R_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (105)$$

If $M$ is fixed and $R_2$ required, (105) yields

$$R_2 = \frac{R(\cos c - \cos a)}{1 - \cos c} = \frac{R(\cos c - \cos a)}{\text{versin } c} \quad . \quad . \quad (106)$$

**Example.**—Take same example as in preceding cases.

By (105), $\cos c = 0.54403 = \cos 57° \, 02'$.

Then $a - c = 64° \, 32' - 57° \, 2' = 7° \, 30'$, calling for a distance of 7.50 stations from $A$ to $M$ around 1° curve. From $M$ to $H$ on 4° curve is 14.258 stations.

### 130. To Locate a Y

A Y is made up of a system of tracks so arranged as to admit of turning an entire train. Three of the most used arrangements are given below.

FIRST CASE.—*One branch of Y a straight line.*

This is only the special case of the last problem in which the cutting line becomes tangent to both curves. In Fig. 56, if any one of the points $A$, $B$, or $C$ is given, the others may be located by finding the angles $c$ and $b$. Draw $O_1E$ parallel to $CA$; then in triangle $OO_1E$

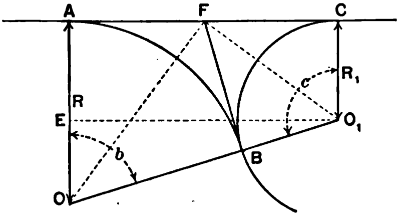


FIG. 56.

$$(R + R_1) \cos b = R - R_1.$$

$$\therefore \cos b = \frac{R - R_1}{R + R_1}. \quad \ldots\ldots \quad (107)$$

This follows at once from (103) by making angle $a = 0$. Then angle $c = 180 - b$. If $AB$ were a located curve and the point $B$ given, formula (107) would furnish us a value for $R_1$.

*Another solution* is to produce the tangent at $B$ to cut $AC$ at $F$; then $AF = FC = BF$. Join $F$ with $O$ and $O_1$; it can easily be seen that angle $OFO_1 = 90°$, and, by geometry,

$$BF = \sqrt{R \times R_1}. \quad \ldots\ldots \quad (108)$$

Therefore $$\tan \tfrac{1}{2}b = \frac{BF}{R} = \sqrt{\frac{R_1}{R}}, \quad \ldots\ldots \quad (109)$$

and $$\tan \tfrac{1}{2}c = \frac{BF}{R_1} = \sqrt{\frac{R}{R_1}}. \quad \ldots\ldots \quad (110)$$

**Example.**—Let $AB$ be a 8° curve, $BC$ a 6° curve, the point $A$ at station 180.

By (107),

$$\cos b = \frac{1910.1 - 955.4}{1910.1 + 955.4} = 0.33317 = \cos 70^\circ\ 32'.$$

The number of $B$ is $180 + 23.511 = 203 + 51.1$. Angle $c = 109^\circ\ 28'$, equivalent to 18.244 stations on the 6° curve.

Second Case.—*The three branches curved and convex towards each other.*

Given the three radii and any one of the points $A$, $B$, or $C$, Fig. 57, we have only to find the angles at the center, then divide these angles by the degrees of the respective curves to get their lengths and locate the three branches.

In the triangle $OO_1O_2$, letting $OO_1 = l$, $O_1O_2 = m$, $OO_2 = n$, $s = \frac{1}{2}(l + m + n) = R + R_1 + R_2$, we shall have, by trigonometry,

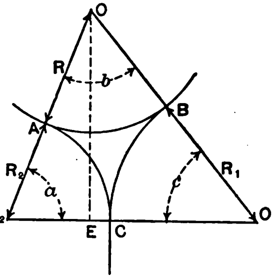


Fig. 57.

$$\cos \tfrac{1}{2}a = \sqrt{\frac{s(s-l)}{m\,.\,n}} = \sqrt{\frac{(R + R_1 + R_2)R_2}{(R + R_2)(R_1 + R_2)}}. \quad . \quad (111)$$

Angles $b$ and $c$ may be found in like manner.

The angles may be found otherwise by letting fall a perpendicular from one vertex upon the opposite side, as $OE$ perpendicular to $O_1O_2$. Then from the relation

$$O_1O_2 : O_1O + OO_2 = OO_1 - OO_2 : O_1E - O_2E$$

determine $O_2E$ and $O_1E$; then the right triangles $O_2OE$ and $O_1OE$ yield values of cosine $a$ and cosine $c$, after which $b$ may readily be obtained.

Third Case.—*One branch concave to the other two.*

In Fig. 58 the triangle $OO_1O_2$ may be solved for the angles at $O$, $O_1$, and $O_2$; for if the radii are given, the sides $OO_1 = R - R_1$, $OO_2 = R - R_2$, and $O_1O_2 = R_1 + R_2$ are known and the solution is the same as for second case. Then $b$ is the central angle for curve $AB$, $a' = 180 - a$, the central angle for $AC$, and $c' = 180 - c$, the central angle for curve $BC$.

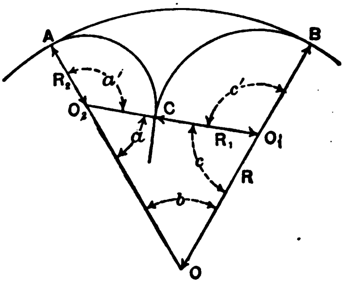


FIG. 58.

EXAMPLE.—If $A$ is at sta. 820 on the 1° curve $AB$, $AC$ an 8° curve, connect with a 6° curve $CB$. Here we have

$$O_2O = 5730 - 717 = 5013, \quad O_1O = 5730 - 955 = 4775,$$

and

$$O_2O_1 = 955 + 717 = 1672.$$

Solving this triangle, we get $c = 88° 20'$, $b = 19° 28'$, and $a = 72° 12'$. The number of $B$ is therefore $820 + 19.467 = 839 + 46.7$; the length of $CB$ is $\frac{91.667}{6} = 15.278$ stations, and of $AC$ is $\frac{107.8}{8} = 13.475$ stations.

### 131. To Locate a Reversed Curve between Parallel Tangents

FIRST CASE.—*Radii equal.*

(*a*) The equal radii $R$ and distance $p$ between tangents known. In Fig. 59 draw $OE$ parallel to $AG$ to meet $O_1B$ produced. From triangle $OEO_1$,

$$\cos a = \frac{2R - p}{2R} = 1 - \frac{p}{2R}, \quad . \quad . \quad . \quad . \quad (112)$$

and

$$OE = 2R \sin a. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (113)$$

From triangle $ABG$,

$$AB = \frac{p}{\sin \frac{1}{2}a} = p \operatorname{cosec} \tfrac{1}{2}a = \sqrt{OE^2 + p^2}. \quad . \quad (114)$$

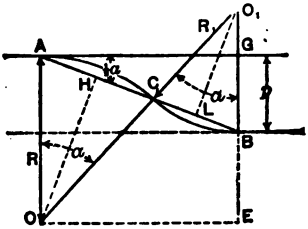


Fig. 59.

($b$) $AG$ and $p$ known, $R$ required.

Here $AB = \sqrt{AG^2 + p^2} = k$. Draw $OH$ to the mid-point of $AC$. Triangles $AOH$ and $ABG$ are similar and $AH = \frac{1}{4}k$. Therefore

$$\frac{R}{\frac{1}{4}k} = \frac{k}{p},$$

whence

$$R = \frac{k^2}{4p}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (115)$$

Example.—Connect two parallel tracks, 30 ft. c. to c. by a 7° reversed curve. From Table I, $R = 819$ feet, and, by (112),

$$\cos a = 1 - \frac{30}{1638} = 0.98167 = \cos 10° \, 59'.$$

By (113), $OE = 1638 \times .19052 = 312.1$ feet.

By (114), $AB = \sqrt{(312.1)^2 + (30)^2} = 313.5$ feet.

If $p = 30$, $OE = 312.1$, or $AB = 313.5$ had been given, we should have had, by (115)

$$R = \frac{(313.5)^2}{120} = 819 \text{ feet.}$$

SECOND CASE.—*Radii unequal.*

(*a*) Suppose the radii $R = OA$ and $R_1 = O_1B$ (Fig. 59) to be known. We must find central angle $a$ and $AB = k$. From the triangle $OO_1E$,

$$\cos a = \frac{R + R_1 - p}{R + R_1} = 1 - \frac{p}{R + R_1}. \quad . \quad . \quad (116)$$

Then $AB$ will be given by (114).

(*b*) Suppose $AB = k$, $p$ and $R$ known, to find $R_1$ and angle $a$. Triangle $ABG$ yields

$$\sin \tfrac{1}{2}a = \frac{p}{k}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (117)$$

$O_1LB$ is similar to $AGB$. Hence

$$\frac{R_1}{LB} = \frac{k}{p}.$$

But $AC = 2R \sin \tfrac{1}{2}a$, and $LB = \tfrac{1}{2}(k - AC) = \tfrac{1}{2}C_1$. Inserting this value of $LB$ and solving for $R_1$,

$$R_1 = \frac{kC_1}{2p}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (118)$$

From similar triangles,

$$\frac{R_1}{R} = \frac{C_1}{k - C_1}.$$

Inserting the value of $C_1 = \frac{2pR_1}{k}$ from (118) and solving for $R_1$, we get

$$R_1 = \frac{k^2}{2p} - R. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (119)$$

EXAMPLE.—$AB = 300'$, $p = 30'$, $R = 819$ ft., to find angle $a$ and $R_1$.

By (117), $\sin \tfrac{1}{2}a = \frac{30}{300} = 0.10000 = \sin 5° 44'$.

Therefore angle $a = 11° 28'$.

By (119). $R_1 = \frac{(300)^2}{60} - 819 = 681$ ft., an 8° 25′ curve.

### 132. To Connect Two Parallel Tracks by a Crossover composed of two $D°$ Curves with a Given Length of Tangent between Points of Contrary Flexure.

In Fig. 60 let $AFGB$ be the required crossover, $FG = l$, $EB = p$, and $OA = O'B = R$ known; angle $a$ and $AE = x$ are required.

Draw $OM$ parallel to $AE$ to meet $O'B$ produced; draw also $OC$ parallel and equal to $FG$; join $O$ and $O'$. From triangle $OO'C$,

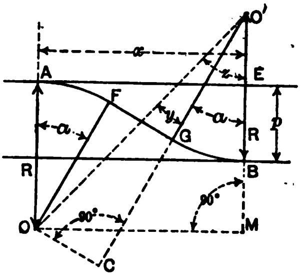


FIG. 60.

$$\tan y = \frac{l}{2R}, \quad . \quad . \quad . \quad . \quad (120)$$

$$OO' = \frac{2R}{\cos y} = 2R \sec y = \sqrt{4R^2 + l^2}. \quad . \quad . \quad (121)$$

Then in triangle $OO'M$,

$$\cos z = \frac{O'M}{OO'} = \frac{2R - p}{2R \sec y} = \left(1 - \frac{p}{2R}\right) \cos y. \quad . \quad (122)$$

Now knowing $y$ and $z$,

$$a = z - y. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (123)$$

Next, $$x = OM = OO' \sin z = 2R \sec y \sin z. \quad . \quad (124)$$

EXAMPLE.—Given $D = 7° 30'$, $p = 62$ ft., $l = 100$ ft., to locate crossover when $A$ is at sta. 86 + 20.

By (120),

$$\log \tan y = 2 - 3.18441 = 8.81559 = \log \tan 3° 44'.$$

By (121),

$$\log OO' = 3.18441 - 9.99908 = 3.18533 = \log 1532.$$

By (122),

$$\log \cos z = 3.16643 - 3.18533 = 9.98110 = \log \cos 16° 47'.$$

By (123),

$$a = 16° 47' - 3° 44' = 13° 3'.$$

By (124),

$$\log x = 3.18533 + 9.46053 = 2.64586 = \log 442.4.$$

### 133. To Find the Radius of the Reversed Curve $AFE$, Fig. 61, Given Angles $I$ and $I'$, and $BC = k$.

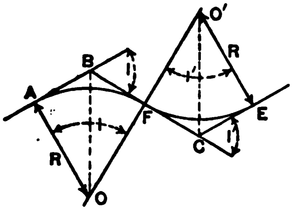


FIG. 61.

From the figure,

$$R \tan \tfrac{1}{2}I = BF,$$

$$R \tan \tfrac{1}{2}I' = CF.$$

Adding,

$$R(\tan \tfrac{1}{2}I + \tan \tfrac{1}{2}I') = BC = k.$$

Whence

$$R = \frac{k}{\tan \tfrac{1}{2}I + \tan \tfrac{1}{2}I'}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (125)$$

EXAMPLE.—Given $I = 10°$, $I' = 20°$, $BC = 700$ feet, to find $R$.

By (125), $R = \dfrac{700}{0.08749 + 0.17633} = 2653$ ft., a 2° 9¼' curve.

### 134. To Locate a Reversed Curve between Fixed Points.

In Fig. 62 let $AB = k$, and angles $I$ and $I'$ be known. We

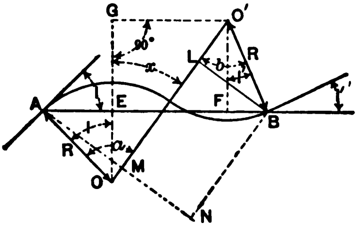


FIG. 62.

have to find $R$ and the angles $a$ and $b$.

Draw $O'G$ parallel to, and $OG$ and $O'F$ perpendicular to, $AB$. Angle $AOG = I$ and $BO'F = I'$. Then $OE = R \cos I$ and $O'F = R \cos I'$. Hence

$$OG = R(\cos I + \cos I').$$

In triangle $OO'G$, $OO' = 2R$. Therefore

$$\cos x = \frac{R(\cos I + \cos I')}{2R} = \frac{\cos I + \cos I'}{2}, \quad . \quad (126)$$

an expression from which $R$ has disappeared.

We now have $a = I + x$ and $b = I' + x$.

To find $R$ we have $AE + EF + FB = k$,

or $R \sin I + 2R \sin x + R \sin I' = k$.

Whence
$$R = \frac{k}{\sin I + \sin I' + 2 \sin x}. \quad . \quad . \quad (127)$$

*Another expression* for $R$ can be found by drawing $AN$ and $BL$ perpendicular to $OO'$, and $BN$ parallel thereto. Then, since $\measuredangle BAN = x$,

$$R \sin a + R \sin b = k \cos x.$$

$$\therefore \quad R = \frac{k \cos x}{\sin a + \sin b}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (128)$$

Example.—Take the example of the last problem,

$$k = 700, \quad I = 10°, \quad I' = 20°.$$

By (126),

$$\cos x = \tfrac{1}{2}(0.98481 + 0.93969) = 0.96225 = \cos 15° \, 48'.$$

We now have $a = 25° \, 48'$ and $b = 35° \, 48'$.

By (128), $R = \dfrac{700 \times 0.96225}{0.43523 + 0.58496} = 660.2$ ft., an 8° 41′ curve.

**135. To Connect Two Divergent Tangents by a Reversed Curve.**

First Case.—*Advancing towards the P.I.*

Given the radii $R$ and $R_1$, the angle $I$ and $AC = k$, to find the angles $a$ and $b$ (Fig. 63).

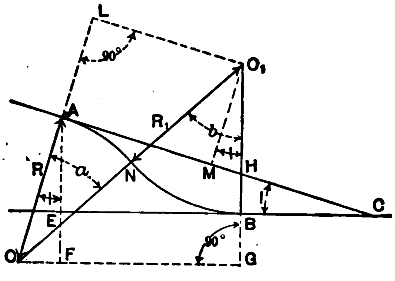


Fig. 63.

Draw $OG$ parallel to the tangent $BC$ to meet $O_1B$ produced.

Then $EF = BG = AF - AE$.

Therefore $BG = R \cos I - k \sin I$.

From triangle $OO_1G$,

$$\cos b = \frac{R_1 + BG}{R + R_1} = \frac{R_1 + R\cos I - k\sin I}{R + R_1}. \quad . \quad (129)$$

Then $a = MO_1N = b - I$, $O_1M$ being parallel to $OA$.

SECOND CASE.—*Receding from the P.I.*

In Fig. 63 we have $BC = k_1$, angle $I$, $R$, and $R_1$ given, to find angles $a$ and $b$.

Produce $OA$ to meet $O_1L$ drawn parallel to $CA$. $AL$ equals $O_1M = O_1H\cos I$.

$$O_1H = R_1 - HB = R_1 - k_1\tan I.$$

$$\therefore\ AL = O_1M = (R_1 - k_1\tan I)\cos I.$$

Hence

$$OL = R + (R_1 - k_1\tan I)\cos I = R + R_1\cos I - k_1\sin I.$$

From triangle $OO_1L$,

$$\cos a = \frac{OL}{OO_1} = \frac{R + R_1\cos I - k_1\sin I}{R + R_1}. \quad . \quad . \quad (130)$$

Evidently, $b = a + I$.

### 136. To Change the *P.R.C.* so that Second Branch o Curve shall End in a Tangent Parallel to Terminal Tangen and Distant *p* therefrom.

In Fig. 64 let $MAB$ be the located curve, $EN = p$. We mu

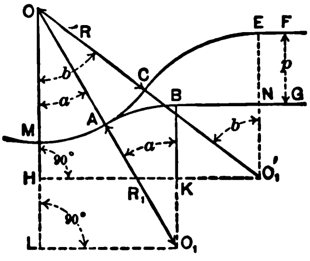


FIG. 64.

determine the angle $COA$, after which the desired curve $A$ may be located.

Draw $HO_1'$ and $LO_1$ parallel to $EF$ and $NG$.

$$HL = O_1K = p.$$

From triangles $OO_1'H$ and $OO_1L$,

$$(R + R_1) \cos b = (R + R_1) \cos a - p.$$

$$\therefore \cos b = \cos a - \frac{p}{R + R_1}. \quad . \quad . \quad . \quad . \quad (131)$$

Angle $AOC = b - a$.

**137. To Find the Radius of a Curved Track.**

Measure any chord $AB = 2l$, and mid-ordinate $CE = M$.

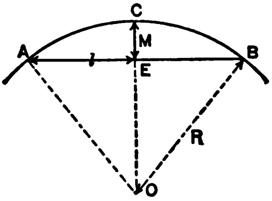


FIG. 65.

Then in the right triangle $OAE$ (Fig. 65),

$$R^2 - (R - M)^2 = l^2.$$

$$\therefore R = \frac{l^2 + M^2}{2M}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (132)$$

NOTE.—The treatment of the problems of Sections **129, 130, 131, 132,** and **135** is based on the assumption that both switch-rails and frogs are curved. The results are usually close enough if shortened leads are used, as will be mentioned later. The effect of straight switch-rails and frogs will be discussed later on.

# CHAPTER IV

## *TRANSITION-CURVES.*

### ARTICLE 11.—THEORY OF THE TRANSITION-CURVE.

**138. Elevation of Outer Rail on Curves.**—To counteract the effect of centrifugal force on curves the outer rail must be elevated above the inner one. It is shown in mechanics that the centrifugal force is

$$F = \frac{Wv^2}{32.16R},$$

where $W$ is the weight, $v$ the velocity in feet per second, 32.16 an average value of the acceleration of gravity in feet per second per second, and $R$ the radius in feet.

In Fig. 66 let the vertical $HL$ represent $W$, the horizontal $KH$ the centrifugal force, $AB$ the plane of the rails, and $CB = e$ the superelevation of outer rail. From similar triangles,

$$F = W\frac{e}{AC}.$$

Equate this value of $F$ to that given above and solve for $e$, giving

$$e = \frac{ACv^2}{32.16R}. \quad . \quad . \quad (133)$$

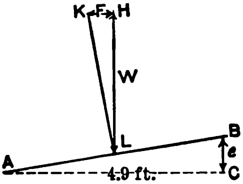


FIG. 66.

The gauge $AB$ should be greater on curves than on tangents to allow for flange clearance and the effect of a rigid wheel-base. $AC$ = 4.9 feet is about the right value for the horizontal distance between centers of rail-heads for standard gauge. In formula (133) $v$ is in feet per second, but the train velocity is usually given in miles per hour. Let $V$ = velocity in miles per hour, then the velocity in feet per second will be $v = \frac{22}{15} V$. Inserting these values in (133) gives

$$e = \frac{4.9 \times 484 V^2}{32.16 \times 225 R} = \frac{V^2}{3R}, \text{ nearly.} \quad . \quad . \quad . \quad (134)$$

This elevation will be required from the *P.C.* to the *P.T.*, but obviously it cannot be introduced suddenly, so that for easy riding the rate of increase of $e$ should be uniform. From (134) it is seen that $e$ varies inversely with $R$, which requires that when $e = 0$, $R =$ infinity. Hence $R$ must decrease from infinity to the radius of the circular curve, while $e$ increases from 0 to its maximum value.

**139. The True Transition-curve** should satisfy formula (134), but so far no such curve has been found that will at the same time admit of the same ease of location as the simple circular curve. According to Rankine the first use of any other than the circular curve was made by Gravatt about 1828 or 1829, the curve employed being the curve of sines. Another method described by Rankine is attributed to William Froude about 1842; this curve was worked up in the *Engineering News* by A. M. Wellington in 1890. Other approximations are the *Railroad Spiral*, developed by W. H. Searles in 1882, and the cubic parabola, described by C. D. Jameson and E. W. Crellin in the *Railroad and Engineering Journal*, 1889.

In 1880 Elliot Holbrook described in the *Railroad Gazette* the true transition-curve applicable to small angles and short lengths of the curve. In 1893 C. L. Crandall published formulæ and tables applicable to large central angles for both the offset and deflection methods.

**140. The Notation** here employed will be explained with reference to Fig. 67. The curve *CBB'C'* is the circular curve offset at $C$ and $C'$ from the tangents by the amounts $CH$ and $C'H'$. $AGB$ and $B'G'A'$ are the transition-curves. $A$ is the *P.T.C.*, or point of transition-curve, $C$ the *P.C.*, $B$ the *P.C.*$_1$, $B'$ the *P.T.C.*$_1$, $C'$ the *P.T.*, and $A'$ the *P.T.*$_1$. The co-ordinates of $G$ are $AH = x'$, $HG = y'$; of $C$, $x'$ and $HC = F$; of $B$, $AM = x_1$ and $MB = y_1$. The length of curve from *P.T.C.* to any point $P$ is $l$, and the whole length from *P.T.C.* to *P.C.*$_1$ is $l_1$.

**141. Equation of Transition-curve.**—Since the rate of change of $e$ must be uniform, (134) may be written

$$e = kl = \frac{V^2}{3\rho}, \quad \ldots\ldots\ldots \quad (135)$$

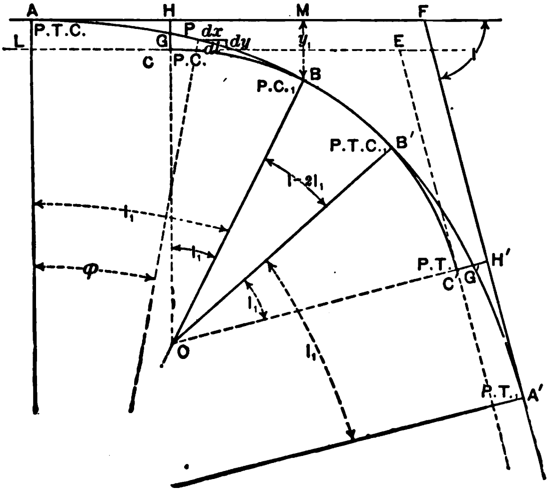


FIG. 67.

in which $k$ is the rate of rise of outer rail along curve, and $\rho$ the varying radius of curvature. From the calculus $\rho d\phi = dl$, whence

$$\rho = \frac{dl}{d\phi}. \quad \ldots\ldots\ldots \quad (136)$$

Insert this in (135) and solve for $d\phi$.

$$d\phi = \frac{3k}{V^2}ldl = 2mldl. \quad \ldots\ldots \quad (137)$$

$2m$ is dependent upon $V$ and $k$, and is constant for any one curve.

Integrating (137),

$$\phi = ml^2, \quad \ldots\ldots\ldots \quad (138)$$

the constant of integration being zero, for $l$ is zero when $\phi$ is zero.

From the elementary triangle drawn at the point $P$ of transition-curve, Fig. 67, $dl$ being tangent,

$$\frac{dy}{dl} = \sin \phi.$$

Expanding $\sin \phi$ by trigonometry,

$$dy = dl\left(\phi - \frac{\phi^3}{3!} + \frac{\phi^5}{5!} - \frac{\phi^7}{7!} + \ldots\right),$$

in which $3! = 3 \times 2 \times 1$, $5! = 5 \times 4 \times 3 \times 2 \times 1$, etc.

Substituting for $\phi$ its value from (138),

$$dy = dl\left(ml^2 - \frac{m^3l^6}{6} + \frac{m^5l^{10}}{120} - \frac{m^7l^{14}}{5040} + \ldots\right).$$

Integrating,

$$y = \left(\frac{ml^3}{3} - \frac{m^3l^7}{42} + \frac{m^5l^{11}}{1320} - \frac{m^7l^{15}}{75600} + \ldots\right). \quad . \quad . \quad (139)$$

But $ml^2 = \phi$, where $\phi$ is in circular measure. To obtain $\phi$ in degrees, $\phi = \phi^\circ \frac{\pi}{180} = \frac{\phi^\circ}{57.3}$. Inserting this in (139),

$$y = l\left(\frac{\phi^\circ}{171.89} - \frac{\phi^{\circ 3}}{79 \times 10^5} + \frac{\phi^{\circ 5}}{8151 \times 10^8} - \frac{\phi^{\circ 7}}{153245 \times 10^{12}} + \ldots\right),$$

$$\text{or} \qquad y = lC, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (140)$$

in which $C$ may be found from Table XIV with $\phi^\circ$ as argument. Interpolation must be resorted to for values of $\phi$ not given in the table, or $y$ computed by the formula.

From the elementary triangle at $P$, Fig. 87

$$\frac{dx}{dl} = \cos \phi.$$

Expanding by trigonometry,

$$dx = dl\left(1 - \frac{\phi^2}{2!} + \frac{\phi^4}{4!} - \frac{\phi^6}{6!} + \ldots\right).$$

Substituting $ml^2$ for $\phi$ and integrating,

$$x = l\left(1 - \frac{m^2l^4}{10} + \frac{m^4l^8}{216} - \frac{m^6l^{12}}{9360} + \ldots\right). \quad . \quad . \quad . \quad . \quad (141)$$

Replacing $ml^2$ by $\phi$ reduced to degrees,

$$x = l\left(1 - \frac{\phi^{\circ 2}}{32828} + \frac{\phi^{\circ 4}}{2328 \times 10^6} - \frac{\phi^{\circ 6}}{33114 \times 10^{10}} + \ldots\right)$$

$$\text{or} \qquad x = l - lE. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (142)$$

$E$ varies with $\phi^\circ$, and may be taken from Table XIV with $\phi^\circ$ as argument..

**142. The Transition-curve Angle** $I_1$ is the value $\phi$ assumes at the $P.C._1$. From (138),

$$I_1 = ml_1^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (143)$$

From (137) and (136),

$$\frac{dl}{d\phi} = \frac{1}{2ml} = \rho.$$

At the $P.C._1$ $\rho = R$ and may be taken equal to $\frac{5730}{D^\circ}$, so that

$$\frac{1}{2ml_1} = R = \frac{5730}{D^\circ},$$

whence

$$m = \frac{1}{2l_1R} = \frac{D^\circ}{11460l_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (144)$$

This value of $m$ in (143) gives

$$I_1 = \frac{l_1}{2R} = \frac{D^\circ l_1}{11460}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (145)$$

Reducing this to circular measure by writing $I_1 = I_1^\circ\frac{\pi}{180} = \frac{I_1^\circ}{57.30}$ gives

$$I_1^\circ = 28.65\frac{l_1}{R} = \frac{D^\circ l_1}{200}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (146)$$

**143. The Coördinates** of any point on the curve are given by (140) and (142). The length of the transition-curve being known or assumed, $y_1$ and $x_1$ (the coördinates of the $P.C._1$) may be found from these equations by the help of Table XIV; the coördinates of the $P.C.$ (see Fig. 67) will be

$$F = y_1 - R(1 - \cos I_1) = y_1 - R \operatorname{vers} I_1, \quad . \quad . \quad (147)$$

$$x' = x_1 - R \sin I_1 . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (148)$$

**144. Deflection-angles.**—With the transit at the $P.T.C.$ (or $P.T._1$ in backing up) the tangent of deflection-angles may be found from the relation $\tan \delta = \frac{y}{x}$. Dividing (139) by (141),

$$\tan \delta = \frac{ml^2}{3} + .009523m^3l^6 + .000167m^5l^{10} + \ldots . \quad (149)$$

From trigonometry the expansion of the angle in terms of its tangent is

$$\delta = \tan \delta - \tfrac{1}{3} \tan^3 \delta + \tfrac{1}{5} \tan^5 \delta - \text{etc.} \quad . \quad . \quad . \quad (a)$$

In (149) write $ml^2 = \phi$ and substitute in $(a)$:

$$\delta = \frac{\phi}{3} - .002823\phi^3 - .000068\phi^5 . \quad . \quad . \quad . \quad . \quad (150)$$

From (138) and (143),

$$\frac{\phi}{I_1} = \frac{ml^2}{ml_1^2} = \frac{l^2}{l_1^2} = n^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

in which $\frac{l}{l_1} = n$. From $(b)$, $\phi = I_1 n^2$, and this in (150) gives

$$\delta = \frac{I_1}{3} n^2 - .002823 I_1^3 n^6 - .000068 I_1^5 n^{10} . \quad . \quad . \quad . \quad (c)$$

Both $\delta$ and $I_1$ are in circular measure; to reduce to degrees multiply by $\frac{\pi}{180}$. This gives, neglecting terms involving higher powers of $I_1$ than the third,

$$\delta^\circ = \frac{I_1^\circ}{3} n^2 - .00000086\, I_1^3 n^6 . \quad . \quad . \quad . \quad . \quad . \quad (151)$$

The second term is quite small, and in most cases may be entirely neglected in practice.

With the instrument at any intermediate point $x''y''$ the deflection-angle for any point $xy$, measured from initial tangent, will be

$$\tan\delta = \frac{y - y''}{x - x''} = \tfrac{1}{3}(ml^2 + ml''^2 + mll'') + \tfrac{1}{105}(m^3l^6 + m^3l''^6)$$
$$+ \tfrac{3}{70}(m^3l^5l'' + m^3ll''^5) + \tfrac{8}{105}(m^3l^4l''^2 + m^3l^2l''^4 + m^3l^3l''^3) + \ldots, \quad (152)$$

in which powers of $ml^2$ higher than the third have been neglected.

Substitute the value of $\tan\delta$ from (152) in $(a)$, write $ml^2 = \phi = I_1n^2$, $ml''^2 = \phi'' = I_1n''^2$, by $(b)$, and reduce circular measure to degrees, giving

$$\delta_0 = \frac{I_1^\circ}{3}(n^2 + n''^2 + nn'') - \text{a small correction.} \quad (153)$$

For instrument at *P.T.C.*, $n'' = 0$; then (153) yields

$$(\delta_0^\circ) = \frac{I_1^\circ}{3}n^2 - \text{correction,}$$

or

$$(\delta_0^\circ) = \frac{I_1^\circ}{3}A_0 - B_0 \,. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (154)$$

(154) is the same as (151), as it should be.

For the transit at the quarter-point of transition-curve $n'' = \frac{l''}{l_1} = \frac{\frac{1}{4}l_1}{l_1} = \frac{1}{4}$; then (153) yields

$$(\delta_{\frac{1}{4}}^\circ) = \frac{I_1^\circ}{3}(n^2 + \tfrac{1}{16} + \tfrac{1}{4}n) - \text{correction,}$$

or

$$(\delta_{\frac{1}{4}}^\circ) = \frac{I_1^\circ}{3}A_{\frac{1}{4}} - B_{\frac{1}{4}} \,. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (155)$$

For transit at mid-point of transition-curve $n'' = \frac{1}{2}$, and, from (153),

$$(\delta_{\frac{1}{2}}^\circ) = \frac{I_1^\circ}{3}(n^2 + \tfrac{1}{4} + \tfrac{1}{2}n) - \text{correction,}$$

or

$$(\delta_{\frac{1}{2}}^\circ) = \frac{I_1^\circ}{3}A_{\frac{1}{2}} - B_{\frac{1}{2}} \,. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (156)$$

**For transit at three-quarter point $n'' = \frac{3}{4}$ and**

$$(\delta_{\frac{3}{4}}{}^\circ) = \frac{I_1{}^\circ}{3}(n^2 + \tfrac{9}{16} + \tfrac{3}{4}n) - \textbf{correction},$$

**or**

$$(\delta_{\frac{3}{4}}{}^\circ) = \frac{I_1{}^\circ}{3}A_{\frac{3}{4}} - B_{\frac{3}{4}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (157)$$

**For transit at $P.C._1$ $n'' = 1$ and**

$$(\delta_1{}^\circ) = \frac{I_1{}^\circ}{3}(n^2 + 1 + n) - \textbf{correction},$$

**or**

$$(\delta_1{}^\circ) = \frac{I_1{}^\circ}{3}A_1 - B_1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (158)$$

With the transit at the $P.T.C._1$ it will frequently be most convenient to measure the deflections from the tangent to the circular curve at that point. Sometimes this will also be the case for the transit at the $P.C._1$.

By reference to Fig. 68 it will be seen that for the transit at $B$ the deflection from the tangent to the circular curve at the $P.C._1$, which locates a point on the transition curve (as .6 in the figure), is given by the equation $(\delta_c{}^\circ) = I_1 - (\delta_1{}^\circ)$, or

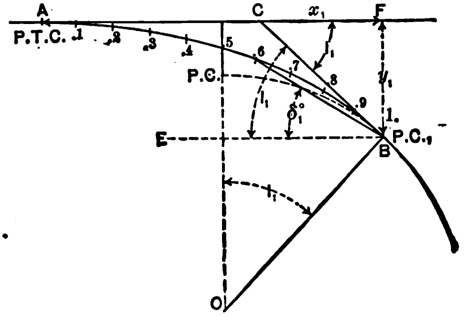


FIG. 68.

$$(\delta_c{}^\circ) = I_1{}^\circ - \left(\frac{I_1{}^\circ}{3}n^2 + \frac{I_1{}^\circ}{3} + \frac{I_1{}^\circ}{3}n - B_1\right) = \frac{I_1{}^\circ}{3}(2 - n^2 - n) + B_1,$$

or, if Table XV is to be used,

$$(\delta_c{}^\circ) = \frac{I_1{}^\circ}{3}A_c + B_1. \quad . \quad . \quad . \quad . \quad . \quad (159)$$

Table XV gives the values of $A$ and $B$ for the five positions of instrument for which equations (154) to (159), inclusive, were deduced. The value of $A$ must be multiplied by $\frac{I_1{}^\circ}{3}$, but $B$ is taken direct from the table in thousandths of a degree.

If deflection-angles are wanted for other positions of the instrument, or for other points on the curve, they may be computed from equation (153).

**145. Tables.**—Three tables are given for use with transition-curves.

Table XIV was computed for use with formulas (140) and (142) in determining $C$ and $E$; $\phi$ being assumed and $C$ and $E$ computed.

Table XV gives $A$ and $B$ for computing the deflection-angles by (154), (155), (156), (157), (158), and (159) for 20 equidistant stations on the transition-curve. For points not given in the table $A$ and $B$ must be interpolated. Linear interpolation will suffice in most cases, though when $I_1{}^\circ$ is quite large second differences may be preferable for $A$. $B$ is given in the table in thousandths of a degree.

Table XVI was calculated by assuming $l_1$ in lengths varying by increments of 20 feet, then computing $I_1{}^\circ$ by (146), $y_1$ by (139), $x_1$ by (141), $F$ by (147), and $x'$ by (148). $y_1$ and $x_1$ will also be given more directly by (140) and (142) with the aid of Table XIV.

The excess in length of transition-curve, measured from $P.T.C.$ to the point on offset at $P.C.$, over $x'$ is tabulated as $e$; $l'$ is found by trial such that when inserted in (141) or (142) the same value of $x'$ will be obtained as in (148). This may be done by assuming $l'$ a little less than $\frac{l_1}{2}$, then computing $x'$. More than two trials will rarely be needed to find a sufficiently close value of $l'$; then $e = l' - x'$. $y'$ is found by (139) after finding $l'$, or $\phi'$ may be found from ($b$) of **144**, and used in (140) in connection with Table XIV. $l_1 - l'$ is the length from $G$ (Fig. 67) to the $P.C._1$; the difference in length between this and the length of circular curve from $P.C.$ to $P.C._1$ is tabulated as $e'$; that is, $e' = (l_1 - l') - \text{arc}$. Then $e + e' = l_1 - (x' + \text{circular arc})$.

For values of $l_1$ intermediate between those given in the table linear interpolation will suffice, though second differences may be used for $F$ and $y_1$ if preferred.

**146. To Unite the Two Branches of a Compound Curve by a Transition-curve.**

The same objections hold to compound curves as to simple curves uniting with a tangent; i.e., where there is a sudden change of curvature there should be a sudden change of super-elevation of outer rail, which of course is not allowable. Instead of compounding the curves, we may offset them at the *P.C.C.* and unite them by means of a portion of a transition-curve tangent to each of the simple curves.

In Fig. 69 *AB* and *CELM* are the simple curves that are to be united by the transition-curve *ANE*. Extend the transition-curve to *G*, where its radius of curvature becomes infinite, and let *GS* be its tangent. Call the length of transition-curve from *G* to *A* $l_1$, from *G* to *E* $l_3$, and from *E* to *A* $l_2$. *E* and *A* are points of tangency of simple and transition curves. Then $l_2 = l_1 - l_3$. The coördinates of *A* are $GS = x_1$, $SA = y_1$; and of *V* (*WV* perpendicular to *GS*), $GW = x_1'$, $WV = F_1$; of *E*, $GP = x_3$, $EP = y_3$; of *L* (*LH* perpendicular to *GS*), $GH = x_3'$, $HL = F_3$. Let $BC = F_2$.

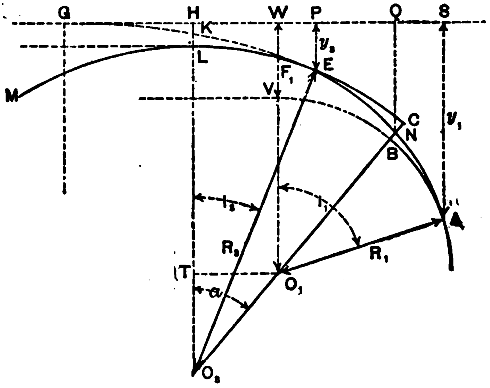


FIG. 69.

The radius of curvature of transition-curve is inversely proportional to its length from *G*; hence the curvature is proportional to the length of curve; therefore $l_3 : l_1 = D_3 : D_1$, whence

$$l_3 = l_1 \frac{D_3}{D_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (160)$$

Then $$l_2 = l_1 - l_3 = l_1\left(1 - \frac{D_3}{D_1}\right) = l_1\frac{D_1 - D_3}{D_1}. \quad . \quad . \qquad (161)$$

By (138) or (143), $$\frac{I_3}{I_1} = \left(\frac{l_3}{l_1}\right)^2.$$

Equating the value of $I_3$ from this equation to that resulting from (146) gives

$$I_3 = I_1\left(\frac{l_3}{l_1}\right)^2 = \frac{l_3 D_3^\circ}{200}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (162)$$

$WV = F_1$ and $HL = F_3$ may be taken from Table XVI with $l_1$ and $l_3$ as arguments. Then $O_1W = R_1 + F_1$ $O_3H = R_3 + F_3$ Draw $O_1T$ parallel to $GS$, then $O_1T = WH$; hence

$$O_3T = (R_3 + F_3) - (R_1 + F_1),$$

and $$O_1T = x_1' - x_3'.$$

Therefore

$$\tan a = \frac{x_1' - x_3'}{(R_3 + F_3) - (R_1 + F_1)}, \quad . \quad . \quad . \qquad (163)$$

$$O_1O_3 = (x_1' - x_3')\operatorname{cosec} a = \sqrt{\overline{O_1T}^2 + \overline{TO_3}^2}. \quad . \qquad (164)$$

Then $$CB = CO_3 - BO_3,$$

or $$F_2 = R_3 - (R_1 + O_1O_3). \quad . \quad . \quad . \quad . \quad . \quad . \qquad (165)$$

The lengths of $AB$ and $CE$ are

$$AB = \frac{I_1^\circ - a^\circ}{D_1}100, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (166)$$

$$CE = \frac{a^\circ - I_3^\circ}{D_3}100. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (167)$$

The excess of transition-curve length over $AB + CE$ is

$$e_2 = l_2 - \left(\frac{I_1^\circ - a}{D_1} + \frac{a - I_1^\circ}{D_3}\right)100. \quad . \quad . \quad . \qquad (168)$$

If *AB* and *CE* are quite sharp, we must take account of the arc excess, so that we have then

$$e_2 = l_2 - \left[\left(\frac{I_1^\circ - a}{D_1} + \frac{a - I_3^\circ}{D_3}\right) 100 + \text{arc excess}\right]. \qquad (168')$$

The arc excess may be taken from the second column of Table IV, which gives the arc length for one station; this multiplied by the number of stations gives the curve length, which may replace the values within the brackets in (168').

**147. Length of Transition-curve to be Taken.**—In practice the rate of change of superelevation of outer rail ordinarily varies from about 1÷1200 to 1÷340. Call this rate $k$; then $kl_1$ must equal the superelevation of outer rail for circular curve. This superelevation will depend both upon the degree of curve and upon the velocity and is generally fixed to suit the fastest moving passenger trains, though in order that it be not excessive for slow moving freight trains, its limit in practice is about 8 inches. Where the superelevation of outer rail is less than 2 inches, transition-curves need not be employed.

By (**135**)

$$kl_1 = \frac{V^2}{3R} = \frac{V^2D}{17190},$$

from which

$$l_1 = \frac{V^2D}{17190k}. \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (169)$$

The following table gives values of $l_1$ in feet *per degree of curve* for a few values of $V$ and $k$.

TABLE OF VALUES OF $l_1$ FOR VARIOUS VALUES OF $V$ AND $k$.

| $k$ | Velocities in Miles per Hour. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| 1 ÷1200 | 63 | 86 | 112 | 142 | 175 | 212 | 252 | 296 | 343 |
| 1 ÷900 | 47 | 64 | 84 | 106 | 131 | 158 | 188 | 221 | 257 |
| 1 ÷600 | 32 | 43 | 56 | 71 | 87 | 106 | 126 | 147 | 171 |
| 1 ÷340 | 18 | 24.5 | 32 | 40.5 | 50 | 60.5 | 72 | 84.5 | 98 |

The following quotation is taken from the Manual of the American Railway Engineering Association, edition of 1911, page 94.

"Easement curves should be used on all curves requiring an elevation of 2 inches or more for the highest permissible speed.

"The choice of easement curves should be governed by the ultimate possibilities as to speed, with consideration as to probable revision of the worst features of alignment, rather than by existing schedule speed.

"On curves of 6 degrees and over, which are limiting curves as to speed, easement curves not less than 240 feet long should be used.

"On curves of less than 6 degrees which are limiting curves as to speed, easement curves should be used whose length in feet is not less than 5⅓ times the speed in miles per hour calculated for an elevation of 8 inches.

"On curves which are not limiting curves as to speed, easement curves should be used whose length in feet, when the rail is elevated for the ultimate speed, will be not less than 30 times the elevation in inches nor less than two-thirds the ultimate speed in miles per hour times the elevation in inches.

"Longer easement curves than the minimum lengths recommended may be used to advantage and often with increased convenience in their application, but any considerable increase in length is wholly unnecessary and should never be made without careful consideration as to the effect on cost. For minor curves, an increase in length of about 50% over the minimum is recommended when such increase will not seriously affect the cost, nor adversely affect the degree of curve. The minimum length recommended should be used in all cases where greater length would adversely affect the degree of curve.

"Easement curves should be used between curves of different degree in the same way that they are used between curves and tangents.

"The curve elevation should be run out in the same distance as the length of easement curve, with no elevation on tangent and full elevation on the circular curve."

The following table shows values of $l_1$ which agree with the minimum values found by above rules for various speeds, to the nearest 20-ft. interval, for which values the necessary quantities may be taken directly from Table XVI. The maximum permissible superelevation of outer rail is limited to about 8 inches. For 3° curves and over, the last value of

$l_1$ given in the table corresponds to this superelevation. For higher speeds than those for which the last value of the length of transition curve is given, where such higher speeds are permissible, the minimum length of $l_1$ should be increased from 10 to 50%.

TABLE OF MINIMUM VALUES OF $l_1$, IN FEET, FOR VARIOUS VALUES OF $V$, IN MILES PER HOUR, AND CURVES VARYING FROM 1 TO 15 DEGREES.

| Degree of Circular Curve. | Velocities in Miles per Hour. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
| 1 | .... | .... | .... | .... | .... | 80 | 100 | 120 | 160 |
| 2 | .... | .... | 80 | 80 | 120 | 160 | 200 | 320 | 320 |
| 3 | 60 | 80 | 100 | 120 | 160 | 220 | 280 | 340 | |
| 4 | 80 | 100 | 120 | 160 | 220 | 300 | | | |
| 5 | 100 | 120 | 160 | 200 | 260 | | | | |
| 6 | 100 | 140 | 180 | 240 | | | | | |
| 7 | 120 | 160 | 220 | 280 | | | | | |
| 8 | 140 | 200 | 260 | | | | | | |
| 9 | 160 | 220 | 280 | | | | | | |
| 10 | 180 | 240 | | | | | | | |
| 11 | 200 | 240 | | | | | | | |
| 12 | 220 | | | | | | | | |
| 13 | 240 | | | | | | | | |
| 14 | 240 | | | | | | | | |
| 15 | 240 | | | | | | | | |

Sometimes the tangent between the *P.T.* of one circular curve and the *P.C.* of the next is so short that even the minimum length of transition curve given above can not be obtained, in which case shorter transition curves must be put in, for even a short transition-curve is better than none. The engineer should, however, endeavor to leave ample room for transition-curves and also, wherever possible, additional intervening tangent.

EXAMPLE.—Required the minimum length of transition-curve to be used when the train velocity is 45 miles per hour and the degree of circular curve 5.

By the first of the two foregoing tables the length of transition-curve would be $40.5 \times 5 = 202.5$ feet, and by the second 200 feet, which is the value to be used unless there is plenty of room for a longer transition-curve, which at the same time will not increase the cost unduly. In such event use 260 or even 300 feet.

When only a short tangent intervenes between two curves shorter transition-curves must be taken, requiring larger values of $k$, so that overlapping may be prevented.

For illustration suppose a 5° curve to be eased off with a transition-curve, the highest train-speed being 45 miles per hour and $k = \frac{1}{600}$. By the table the value of $l_1$ will be $71 \times 5 = 355$ feet, so that we should probably take a 360-ft. transition-curve, requiring an offset of 4.7 feet by Table XVI.

## ARTICLE 12.—FIELD-WORK.

### A *Field Formulas.*

**148.** For the cases most frequently presenting themselves in practice the foregoing formulas may be simplified so as to admit of the rapid location of points on the transition-curve with all the accuracy needed on location, though it is best to use the exact formulas and tables in setting track-centers on the finished road-bed. When the transition-curve angle is quite large it will be better to use the accurate methods on location also, but for the more common cases the following formulas will answer.

**149. Simplified Formulas.**—In (139) and (140) neglect, as small, all the terms following the first, giving

$$y = \frac{ml^3}{3} = \frac{\phi}{3}l = .005818l\phi^\circ \ldots \ldots \quad (170)$$

In (141) and (142) retain only the first two terms

$$x = l\left(1 - \frac{m^2l^4}{10}\right) = l\left(1 - \frac{\phi^2}{10}\right) = l - .00003l\phi^{\circ 2}, \quad . \quad (171)$$

in which the last term is small for short transition-curves and may often be neglected, $x$ being taken equal to $l$.

The values of $m$ and $I_1$ remain as before :

$$m = \frac{1}{2Rl_1} = \frac{D}{11460l_1}, \quad \ldots \ldots \quad (144)$$

$$I_1^\circ = 28.65\frac{l_1}{R} = \frac{l_1D}{200}. \quad \ldots \ldots \quad (146)$$

In (**147**) expand $\cos I_1$, giving

$$F=y_1-R(\tfrac{1}{2}I_1^2-\tfrac{1}{24}I_1^4+\tfrac{1}{720}I_1^6-\ .\ .\ .)$$

Substitute $R=\dfrac{l_1}{2I_1}$, by (145), and retain only first two terms:

$$F=y_1-\frac{l_1I_1}{4}.$$

But $l_1I_1=3y_1$, by (170), since $\phi=I_1$ and $y=y_1$ when $l=l_1$;

$$\therefore\ F=y_1-\tfrac{3}{4}y_1=\tfrac{1}{4}y_1.\quad .\ .\ .\ .\ .\ .\quad (172)$$

At the $P.C._1$ $y=y_1$, $l=l_1$ and $\phi=I_1$, which value substitute in (170) and then write $I=\dfrac{l_1D}{200}$ by (146), $F=\dfrac{1}{4}y_1$ by (172) and there results

$$F=\frac{1}{4}\left(0.005818l_1\times\frac{l_1D^\circ}{200}=0.0000072725l_1^2D\right),\ .\quad (172)_1$$

or, nearly enough, in many cases,

$$F=0.0000073l_1^2D^\circ.\ .\ .\ .\ .\ .\quad (172)'_1$$

By solving ($172_1$) for $l_1$ in terms of $F$ and $D^\circ$, we get

$$l_1=371\sqrt{\frac{F}{D^\circ}}\ \text{(nearly enough)}.\ .\ .\ .\quad (172)_2$$

Expand $\sin I_1$ in (148), and write $R=\dfrac{l_1}{2I_1}$;

$$x'=x_1-R(I_1-\tfrac{1}{6}I_1^3+\tfrac{1}{120}I_1^5-\ .\ .\ .)=x_1-\tfrac{1}{2}l_1+\tfrac{1}{12}l_1I_1^2\ .\ .\ .$$

But $x_1=l_1-\frac{1}{10}l_1I_1^2$, by (171);

$$\therefore\ x'=l_1-\tfrac{1}{10}l_1I_1^2+\tfrac{1}{12}l_1I_1^2-\tfrac{1}{2}l_1=\tfrac{1}{2}l_1\ \text{(nearly)}.\ \ .\quad (173)$$

By (170),

$$y'=\tfrac{1}{3}m(\tfrac{1}{2}l_1)^3=\tfrac{1}{3}m\times\tfrac{1}{8}l_1^3=\tfrac{1}{8}y_1=\tfrac{1}{2}F.\ .\ .\ .\quad (174)$$

In (154), (155), (156), (157), (158), and (159) neglect the correction; then

$$(\delta_0{}^\circ)=\frac{I_1{}^\circ}{3}A_0=\frac{I_1{}^\circ}{3}n^2,\ .\ .\ .\ .\ .\ .\quad (175)$$

$$(\delta_{\frac{1}{2}}{}^\circ)=\frac{I_1{}^\circ}{3}A_1=\frac{I_1{}^\circ}{3}(2-n^2-n).\ .\ .\ .\quad (176)$$

$$(\delta_{\frac{1}{2}}{}^\circ) = \frac{I_1{}^\circ}{3}A_{\frac{1}{2}}, \quad \ldots\ldots\ldots \quad (177)$$

$$(\delta_{\frac{3}{4}}{}^\circ) = \frac{I_1{}^\circ}{3}A_{\frac{3}{4}}, \quad \ldots\ldots\ldots \quad (178)$$

$$(\delta_1{}^\circ) = \frac{I_1{}^\circ}{3}A_1. \quad \ldots\ldots\ldots \quad (179)$$

$$(\delta_c{}^\circ) = \frac{I_1{}^\circ}{3}A_c. \quad \ldots\ldots\ldots \quad (180)$$

**150. Offsets.**—Formula (170) shows that offsets from transition-curve to tangent vary as the cube of the distance from the *P.T.C.*, and it can be shown that offsets from the circular curve to transition-curve follow the same law, reckoning from the *P.C.*$_1$.

Formula (36) may be written

$$z = f(l^3D), \quad \ldots\ldots\ldots \quad (a)$$

in which $D$ is the degree of curve if offset is from tangent, and the difference of degrees if offset is between two curves having a common point of tangency, $l$ being reckoned from the tangent-point.

From (136) and (137),

$$\frac{dl}{d\phi} = \rho = \frac{1}{2ml},$$

and the degree of transition-curve at any point is

$$D_t = \frac{5730}{\rho} = 11460ml = cl. \quad \ldots\ldots \quad (181)$$

Formula (181) shows that the degree of curvature of transition-curve at any point is a function of its length. If the $D$ in (*a*) is the difference between degrees of circular and transition curves, it will equal $D_1 - D_t$, which is also a function of the length; so in (*a*) write $D = f(l)$, giving

$$z = f'(l^3), \quad \ldots\ldots\ldots \quad (182)$$

which shows that the offset between circular and transition curves varies as the cube of the distance from *P.C.*$_1$. The offset at the *P. C.* is known, being half of *F*, and may therefore be found for other points; thus midway between $P.C.$ and $P.C._1$ it will be one eighth of its value at $P.C.$, or $\frac{1}{16}F$

**151. Compound Curves.**—By trial it has been found that $e_2$ —see formulas (168) and (168′)—equals $e + e'$ from Table XVI when the table is entered with $D = D_1 - D_2$ and $l_2$ as arguments, up to about $D_1 l_1 = 8000$, which covers all cases in ordinary railroad practice; so we write

$$e_2 = e + e'. \quad . \quad . \quad . \quad . \quad . \quad . \quad (183)$$

The distance $AB$ on sharper curve is found by trial to equal $\frac{1}{2}l_2$ up to about $D_1 l_1 = 4000$, which answers for the ordinary cases arising in practice. When $D_1 l_1$ is greater than this $AB$ (of Fig. 69) must be found from (166).

The point $N$ can be taken midway between $C$ and $B$, for the radius of transition-curve decreases uniformly from $R_2$ to $R_1$ and may be here taken as their mean; hence the offset $BN = NC = \frac{1}{2}F_2$. Other offsets may be found from the relation given by (182). Thus the offset midway between $A$ and $B$ will be

$$z = \frac{F_2}{2}\left(\frac{\frac{1}{4}l_2}{\frac{1}{2}l_2}\right)^3 = \frac{F_2}{16}.$$

Other offsets may be obtained if desired.

### *B. Setting Out Transition-curves.*

**152. Given $l_1$ to Find $F$, or Given $F$ to find $l_1$.**—In first locating the line it will ordinarily be sufficient to simply offset the curve at the $P.C.$ the amount fixed upon to allow for insertion of the transition-curve and then to run the circular curve in the usual way after bringing the telescope parallel to the tangent from which the offset was taken while the transit was centered over the $P.C.$ At the $P.T.$ a similar offset is made and the tangent parallel to the terminal tangent of the circular curve continued. If the conditions are such that $l_1$ is fixed in length, or can be assumed, $F$ may be computed by $(172)_1$, or may be taken from Table XVI with $l_1$ as argument. If $F$ is given, $l_1$ may be computed by $(172)_2$ or may be taken from Table XVI with $F$ as argument, interpolating if necessary in either case.

**153. Location by Offsets.**—Having given $l_1$ or F, as the case may be, determine $F$ or $l_1$ as suggested in **152**. At the *P.C.* bisect the offset and set a stake at that point; then measure back along tangent the distance $x'$, which for most cases may be taken as $\frac{1}{2}l_1$—see formula (173)—and set a stake, marking it *P.T.C.* From the *P.C.* measure forward around the circular curve a distance equal to $I_1°$ divided by the degree of curve, $D$, which distance approximately equals $\frac{1}{2}l_1$. Here set a stake marked *P.C.*$_1$. At the quarter-point offset from tangent an amount equal to $\frac{1}{16}F$, for, by (170), the offsets are proportional to the cube of the distance from the *P.T.C.*, so that

$$y=\tfrac{1}{2}F\left(\frac{\frac{1}{4}{l_1}^3}{\frac{1}{2}{l_1}^3}\right)=\tfrac{1}{16}F.$$

At the three-quarter point offset, the same amount from circular curve. If the transition-curve is not over 300 feet long, this will be all the points needed for grading, but if longer, other offsets are found in a similar manner for the eighth points.

Example.—Opposite station 2420 on a tangent an offset is to be made to the *P.C.* of a 5° 0′ circular-curve to left and transition-curves inserted, the maximum operating train speed to be 50 miles per hour. Required the values of $l_1$ and $F$, and the offsets at eighth-points of transition-curve, assuming $l_1$ to be 30% longer than the permissible minimum.

By the first table of **147** the minimum value of $l_1$ is $50\times5=250$ feet, while the second table gives 260 feet, this latter value being to the nearest 20-ft. interval. Adding 30% to the first value we get 325 feet, and to the second, 338 feet. We may use either 320 or 340 as the value of $l_1$. We will take 340 feet as the length of transition-curve.

By $(172)_1$, $F=0.0000072725\times(340)^2\times5=4.20$ feet, which is the same value of $F$ found under a 5° curve opposite $l_1=340$ feet in Table XVI. This table also gives $x'=169.9$, but for all practical purposes it might have been taken as 170 feet, or one-half of $l_1$. The excess length of transition-curve over tangent up to the *P.C.* is given as 0.02 foot, which we neglect as relatively small. By formula (146), or by Table XVI, $I_1°=8.5°$ and $y'=2.1$ feet ($=\frac{1}{2}F$ by (174)). Drive a stake 2.1 feet from offset hub on radius through *P.C.* produced, and mark it 2420; measure back along tangent 169.9 feet to station 2418+30.1, and drive a stake marked *P.T.C.* Measure forward around circular curve $8.5 \div 5 = 1.7$ stations $= 170$ feet, and set a stake marked $P.C._1$ at sta. $2421 + 70.1$.

The approximate offsets at the one-eighth, quarter, three-eighths, and one-half points are set off at right angles to the tangent, and from the circular curve on radial lines equal offsets are made, reckoning back from the $P.C._1$. These offsets are:

At mid-point ($=2420$), the offset is $t = \frac{1}{2} \cdot 4.2 = 2.1$ feet.

| | | | | |
|---|---|---|---|---|
| At one-eighth point, | sta. | $2418 + 72.6$, $t = 2.1 \times (\frac{1}{4})^3$ | $=0.033$ | ft. |
| " quarter-point | " | $2419 + 15.1$, $t = 2.1 \times (\frac{1}{2})^3 = 0.033 \times 2^3$ | $=0.26$ | " |
| " three-eighth point | " | $2419 + 57.6$, $t = 2.1 \times (\frac{3}{4})^3 = 0.033 \times 3^3$ | $=0.89$ | " |
| " mid-point, | " | $2420$ $t = \frac{1}{2}F = \frac{1}{2} \times 4.2$ | $=2.10$ | " |
| " five-eighth point | " | $2420 + 42.5$, $t =$ | $=0.89$ | " |
| " three-quarter point | " | $2420 + 85.0$, $t =$ | $=0.26$ | " |
| " seven-eighth point | " | $2421 + 27.5$, $t =$ | $=0.033$ | " |

Offsets at the eighth, quarter, and three-eighth points are set off from the tangent, and those at the five-eighth, three-quarter, and seven-eighth points from the circular curve. If desired, all offsets may be figured from the tangent and set off therefrom. Thus, for the five-eighth point the distance from the $P.T.C.$ of that point is five-fourths of the distance from the $P.T.C.$ to the $P.C.$, and, therefore, $t = 2.1 \times (\frac{5}{4})^3 = 4.1$. At the three-quarter point the offset is equal to $0.26 \times 3^3 = 7.02$ while at the seven-eighth point it is 11.25 feet.

**154. Location by Deflections.**—Ordinarily the entire transition-curve is run from the $P.T.C.$, its length being divided into any convenient number, $n$, equal parts—the correction $B_0$ being neglected. The quantity $A_0$ of (154) and (175) is simply $n^2$. From the $P.C._1$ the circular portion of the curve is run in the usual way to the $P.T.C._1$. The terminal transition-curve may now be backed in from the $P.T._1$ in precisely the same way as the initial transition-curve was run, or it may be run by deflections from the tangent to the circular curve at the $P.T.C._1$. In the latter case Formula (159) applies, or formula (180) may be used by neglecting the small correction $B_1$. In both formulas $A_C = 2 - n^2 - n$. Only in *very* unusual cases will it be necessary to run any part of the curve from the quarter, half- or three-quarter points. This can readily be done, however, by the application of the appropriate formulas in Sections **144** or **149**. Those who prefer to make use of Table XV instead of applying the formulas may take the values of $A_0$, $A_C$, etc., directly from the tables, and these values, when multiplied by one-third of $I_1°$, give the deflection angles to be used. Table XV provides for as many as 20 points on the transition-curve, but ordinarily 10 will suffice and sometimes even 5 or 4. When the table is used the number of chords on the transition-curve must be an aliquot part of 20.

EXAMPLE.—Take the same example as in the last section, for which $l_1=340$ feet and $D=5°$. By formula (146) $I_1°=\frac{340\times5}{200}=8.5°$, the same as given by Table XVI. Assume 8 chord lengths of 40.5 feet each. $\frac{1}{3}I_1°=2.83333°=170'$. By formula (175) the deflection-angles will be, for the transit at the $P.T.C.$ $=$Sta. 3418+30.1:

For sta. 2418+72.6, $(\delta_0°)_{\frac{1}{8}}=170'\times\frac{1}{64}=$ $=0°\ 2.66'$
“ “ 2419+15.1, $(\delta_0°)_{\frac{1}{4}}=170'\times\frac{1}{16}=2.66'\times\ 4=0°\ 10.6'$
“ “ 2419+57.6, $(\delta_0°)_{\frac{3}{8}}=170'\times\frac{9}{64}=2.66'\times\ 9=0°\ 23.9'$
“ “ 2420+ .01, $(\delta_0°)_{\frac{1}{2}}=170'\times\ \frac{1}{4}=2.66'\times16=0°\ 42.5'$
“ “ 2420+42.6, $(\delta_0°)_{\frac{5}{8}}=170'\times\frac{25}{64}=2.66'\times25=1°\ \ 6.4'$
“ “ 2420+85.1, $(\delta_0°)_{\frac{3}{4}}=170'\times\frac{9}{16}=2.66'\times36=1°\ 35.6'$
“ “ 2421+27.6, $(\delta_0°)_{\frac{7}{8}}=170'\times\frac{49}{64}=2.66'\times49=2°\ 10.1'$
“ “ 2421+70.1($=P.C._{.1}$), $(\delta_0°)_1\ =170'$ $=2°\ 50'$

At the other end of circular curve, the deflection-angles, measured from the curve tangent, and taken in order from the $P.T.C._{.1}$ will be, by the application of formula (159), for successive points:

$$(\delta_c°)_{\frac{7}{8}}=(2-\tfrac{49}{64}-\tfrac{7}{8})=170'\times\tfrac{23}{64}=1°\ 1.1'$$
$$(\delta_c°)_{\frac{3}{4}}=170'\times(2-\tfrac{9}{16}-\tfrac{3}{4})=170'\times11=1°\ 56.9'$$

and similarly for other points.

Had we preferred to make use of Table XV, either 10 chords of 34 feet each, or 5 chords of 68 feet each, could have been used. Assume 10. For transit at the $P.T.C.$ the deflection-angles will be

For sta. 2418+64.1, $(\delta_0°)_{.1}=170'\times.01=1.7'$
“ “ 2418+98.1, $(\delta_0°)_{.2}=170'\times.04=1.7'\times4=\ 6.8'$
“ “ 2419+32.1, $(\delta_0°)_{.3}=170'\times.09=1.7'\times9=15.3'$

and similarly for the remaining points.

For the transit at the $P.T.C._{.1}$, deflections from tangent to circular curve, the angles would be:

For first point, 34 feet from instrument,

$$(\delta_c°)_{.9}=170'\times.29=0°\ 49.3'$$

For second point, 68 feet from instrument,

$$(\delta_c°)_{.8}=170'\times.56=1°\ 35.2'$$

and similarly for other points until the $P.T._1$ has been reached. Set up the transit over this point, which is at sta. 2421+70.1 for above example, backsight to the $P.T.C._1$ and deflect $\frac{1}{3}I_1^\circ = 2^\circ\ 50'$, when the telescope will be in tangent and the line may be continued.

**155. The Transit Notes** may be kept in any convenient form which will enable another engineer, whether familiar with that form or not, to readily understand them. The form which follows (see Table on page 136) will answer the purpose the notes given being those for the example of **154** when the angle between terminal tangents is $I = 45^\circ\ 30'$.

It would have been sufficient to have recorded deflection-angles to the nearest minute, or half minute, according to the degree of precision with which the transit vernier can be read, but for the purpose of checking the computations for the foregoing example they have been recorded to the nearest tenth of a minute.

The length of the circular portion of the curve was found from its central angle, which equals $45^\circ\ 30' - 2 \times 8^\circ\ 30' = 28^\circ\ 30'$, to be 570 feet, which brings the $P.T.C._1$ to sta. 2427+40.1. With the transit at station 2421+70.1, set the vernier *back* of the zero to $5^\circ\ 40' (= \frac{2}{3}I_1^\circ)$ and deflect into tangent with vernier reading zero; then run the circular curve to station 2427+40.1. With the transit set over this station set the vernier to 14° 15′ back of the zero if the whole curve has been run from the $P.C._1$, transit the telescope and bring vernier to zero, when the telescope will be in tangent. When the second transition-curve has been run, set up at sta. 2430+80.1, backsight on 2427+40.1 and deflect 2° 50′ into tangent at the $P.T._1$.

The terminal transition-curve is not necessarily of the same length as the initial one for a given circular curve, but in such case it is to be run out in the same manner.

The necessary computations for transition-curves are a little more troublesome than for circular curves because the central angle is proportional to the square of the length of curve from the $P.T.C.$ (see formula (138)) instead of the first power, as for circular curves, and also the angle to be deflected from the tangent when the transit is at the $P.T.C.$ is one-third the central angle instead of one-half. The extra work in making computations is small, however, and otherwise it is as easy to run one curve as the other.

| Station. | | Deflection Angle. | Index Angle. | Central Angle. | Calculated Course. | Magnetic Course. | Remarks. |
|---|---|---|---|---|---|---|---|
| 2433 | | | | | | | |
| 2432 | | | | | | | |
| 2431 | | | | | | | |
| +80.1 | ⊙ *P.T.*$_1$ | | 5° 40′ | 8° 30′ | S 77° 18′ W. | S 77° 15′ W. | |
| +37.6 | | | 5° 16′.1 | | | | $l_1$ = 340 ft. |
| 2430 | | | | | | | $I_1^\circ$ = 8° 30′ |
| +95.1 | | | 4° 46′.9 | | | | $F$ = 4.2 ft. |
| +52.6 | | | 4° 12′.3 | | | | |
| +10.1 | | | 3° 32′.5 | | | | |
| 2429 | | | | | | | |
| +67.6 | | | 2° 47′.3 | | | | |
| +25.1 | | | 1° 56′.9 | | | | |
| 2428 | | | | | | | |
| +82.6 | | | 1° 1′.1 | | | | |
| +40.1 | ⊙ *P.T.C.*$_1$ | 1° 0′ | 14° 15′ | 28° 30′ | | | Total $I$ = 45° 30′ |
| 2427 | | | 13 15′ | | | | |
| 26 | | | 10° 45′ | | | | |
| 25 | | | 8° 15′ | | | | |
| 24 | | | 5° 45′ | | | | |
| 23 | | 2° 30′ | 3° 15′ | | | | |
| 2422 | | 0° 45′ | 0° 45′ | | | | |
| +70.1 | ⊙ *P.C.*$_1$, 5° *C.L.* | | 2° 50′ | 8° 30′ | | | Set vernier at 5° 40′, backsight to 2418 +301. Deflect to 0° and run circular curve. |
| +27.6 | | | 2° 10′.1 | | | | |
| 2421 | | | | | | | |
| +85.1 | | | 1° 35′.6 | | | | |
| +42.6 | | | 1° 6′.4 | | | | $l_1$ = 340 ft., $I_1^\circ$ = 8° 30′ |
| + 0.1 | | | 0° 42′.5 | | | | $F$ = 4.2 ft. |
| 2420 | | | | | | | |
| +57.6 | | | 0° 23′.9 | | | | |
| +15.1 | | | 0° 10′.6 | | | | |
| 2419 | | | | | | | |
| +72.6 | | | 0° 2′.7 | | | | |
| +30.1 | ⊙ *P.T.C.* | | 0° 0′ | | | | |
| 2418 | | | | | | | |
| 17 | | | | | | | |
| 16 | | | | | | | |
| 2415 | | | | | N 57° 12′ W. | N 57° 15′ W. | |

## ARTICLE 13. TRANSITION-CURVE PROBLEMS.

**156. To Find the Tangent Distance and External when Transition-curves are Employed, Offsets Equal.**

In Fig. 70 let $AB$ be the circular curve, $EF$ and $GH$ the transition-curves. Let $EK = HK = T_1$ be the tangent distances, and $NK = E_1$ the external required. Let $LK = T'$. Draw $PV$ perpendicular to $LK$; then in triangle $PVK$, $VK = F \tan \frac{1}{2}I$; $LK = AP + VK$ is now known, or

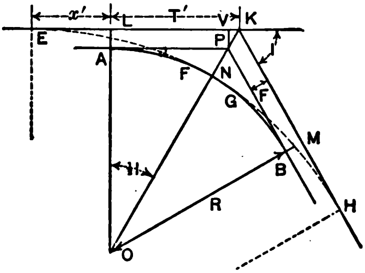


FIG. 70.

$$T' = T + F \tan \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (184)$$

Hence

$$T_1 = x' + T' = x' + T + F \tan \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad (185)$$

In triangle $PVK$, $PK = F \sec \frac{1}{2}I$, so that, letting $PN = E$,

$$E_1 = E + F \sec \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (186)$$

EXAMPLE.—Two tangents intersect at sta. 91 + 37 8; required the tangent and external when $F = 2.62$ ft., $I = 26° 30'$, $D = 4°$.

By Table XVI, $l_1 = 300$, $x' = 149.9$. From Table IX, $T = \frac{1349.2}{4}$ $= 337.3$. Then, by (185),

$$T_1 = 149.9 + 337.3 + 2.62 \tan 13° 15' = 487.8 \text{ ft.}$$

The station number of $P.T.C.$ will now be $91.378 - 4.878 =$ $86 + 50$.

By (186),

$$E_1 = \frac{156.7}{4} + 2.62 \sec 13^\circ\ 15' = 41.87 \text{ ft.}$$

Table XVI gives $I_1° = 6°$; hence the circular curve will cover 26° 30′ − 2 × 6° = 14° 30′, or 3.625 stations, so that the number of the $P.T._1$ will be 86.50 + (2 × 3.00 + 3.625) = 96 + 12.5.

### 157. Tangent Distance, Offsets Unequal.

In Fig. 71, $O$, $N$, and $K$ do not lie in the same straight line.

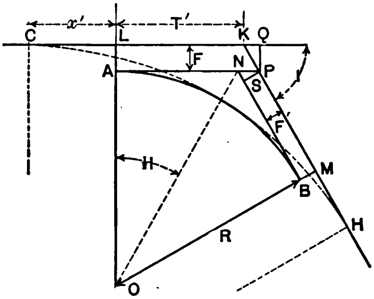


FIG. 71.

Draw $PS$ perpendicular to $NB$, $PQ$ perpendicular to $LK$. Let $LA = F$, $MB = F'$.

$$T' = LK = AN + NP - KQ,$$

or

$$T' = T + F' \operatorname{cosec} I - F \cot I; \quad . \quad . \quad . \quad . \quad . \quad (187)$$

$$T_1 = x' + T' = x' + T + F' \operatorname{cosec} I - F \cot I; \quad (188)$$

$$T'' = MK = T - F' \cot I + F \operatorname{cosec} I; \quad . \quad . \quad . \quad (189)$$

$$T_2 = x'' + T - F' \cot I + F \operatorname{cosec} I. \quad . \quad . \quad . \quad . \quad (190)$$

EXAMPLE.—Two tangents intersect at sta. 820 and are to be united by a 6° curve having $F = 1.75$, $F' = 2.95$, and $I = 31°\ 48'$.

By Table IX, $T = \dfrac{1632.3}{6} = 272.05$ ft.

By Table XVI, $l_1 = 200$, $l_2 = 260$, $x' = 100$, $x'' = 129.9$.

By (188),

$$T_1 = 100 + 272.05 + 2.95 \times \operatorname{cosec} 31° 48' - 1.75 \cot 31° 48' = 374.8.$$

By (190),

$$T_2 = 129.9 + 272.05 - 2.95 \cot 31° 48' + 1.75 \operatorname{cosec} 31° 48' = 400.5.$$

### 158. To Insert Transition-curves without Changing the Position of the Vertex, *B*.

In Fig. 72, *ABC* is the located curve, *FGHK* the curve after inserting transition-curve. The radius of the circular portion has been changed from $R$ to $R'$ in order to make room for the offset $PS = F$. $BM = E$ is the external to located curve, $BL = E'$ the external to circular curve having radius $R'$ and central angle $I$. In the triangle $LNM$, $LM = LN \sec \frac{1}{2}I = F \sec \frac{1}{2}I$; hence

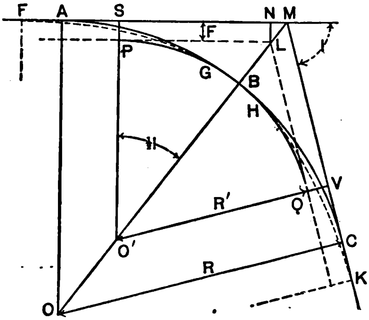


FIG. 72.

$$E' = E - F \sec \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad (191)$$

$E$ may be found by (24) or by means of Table IX; then $E'$ becomes known, and from the same table $D'$ is found by dividing the tabular $E$ by $E'$. $D'$ will be larger than $D$.

It is sometimes more convenient to assume $D'$ and calculate $E'$ in the same manner as $E$; then, from (191),

$$F = (E - E') \cos \tfrac{1}{2}I. \quad . \quad . \quad . \quad . \quad . \quad . \quad (192)$$

If this value of $F$ is too large or too small for the conditions of the problem, a new $D'$ can be assumed and $F$ recomputed.

**Example.**—The *P.C.* of a 5° curve is at sta. 182, and angle $I = 40°$. Compute the data for a new curve to allow for a transition-curve with 1.5 ft. offset.

From Table IX, $E_1 = 367.7$ for $I = 40°$; therefore

$$E = \frac{367.7}{5} = 73.54, \quad F \sec 20° = 1.5 \times 1.0642 = 1.6;$$

then, by (191),

$$E' = 73.54 - 1.60 = 71.94,$$

and

$$D' = \frac{367.7}{71.94} = 5.1113° = 5° \, 6.678', \text{ say } 5° \, 7'.$$

By Table XVI, for $l_1 = 200$, $D = 5° \, 7'$

$$F = 1.45 + \frac{7}{60}(1.75 - 1.45) = 1.485.$$

For $l_1 = 220$,

$$F = 1.76 + \frac{7}{60}(2.11 - 1.76) = 1.801.$$

Then for $F = 1.5$, $D = 5° \, 7'$,

$$l_1 = 200 + 20 \, \frac{1.5 - 1.485}{1.801 - 1.485} = 200.9 \text{ and } x' = 100.4.$$

By (146), $$I_1° = \frac{l_1 D}{200} = \frac{200.9 \times 5.117}{200} = 5.14° = 5° \, 8'.$$

The central angle for circular portion of curve is $40 - 2 \times 5.13 = 29.74°$, equivalent to 581.2 feet around curve.

In Fig. 72, $B$ is at sta. 186 on the 5° curve, and arc $BG = 290.6$ ft. on the 5° 7′ curve. The $P.C._1$ is at 186 − 2.906 = sta. 183 + 09.4, the *P.T.C.* at 183.094 − 2.008 = sta. 181 + 08.6, the $P.T.C._1$ at 188 + 90.6, and the $P.T._1$ at 190 + 91.4.

Had $D'$ been assumed equal to 5° 6′ or 5.1° to begin with, we should have had $E' = \frac{367.7}{5.1} = 72.10$; then, by (192),

$$F = 1.44 \times .93969 = 1.35 \text{ ft.}$$

$l_1$ may be found by interpolation from Table XVI as above.

### 159. To Insert Transition-curves on an Existing Road-bed with the Least Deviation from Old Track.

To satisfy this condition the new track should pass about as far outside the old at the vertex as it does inside at the original $P.C.$; that is, about $\frac{F}{2}$. We shall now have

$$E' = E - F \sec \frac{I}{2} - \frac{F}{2}. \quad . \quad . \quad . \quad . \quad . \quad (193)$$

The remainder of the problem may be solved by **158**.

Transition-curves may be inserted in old track by shifting to suit the existing road-bed, thus adding materially to the safety and easy riding of cars.

### 160. To Insert Transition-curves at the Ends of a Long Circular Curve without Moving the Central Portion.

In Fig. 73, $AC$ is the circular curve. In order to make room for the offset $F$ the ends must be sharpened by compounding. Let $C$ be the point of compounding, $R'$ the radius of the branch $CN$, $HN = KA = F$. Let $BEG$ be the transition-curve; the closer $G$ comes to $C$ the better, provided the change in radius at $C$ is kept within certain limits. The difference in degrees between the original and the sharpened curve should never exceed 2° and may usually be kept in the neighborhood of 1°.

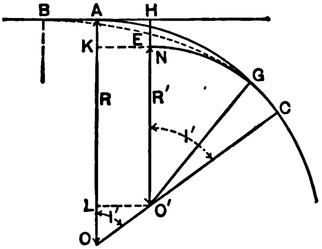


FIG. 73.

FIRST METHOD.—Having decided upon the value of $F$, assume $R'$ so that $D' - D$ is not greater than 2°. Draw $O'L$ parallel to $BH$; $OO' = R - R'$, and $\cos I' = \frac{OL}{OO'}$, or

$$\cos I' = \frac{R - (R' + F)}{R - R'} = 1 - \frac{F}{R - R'}. \quad . \quad (194)$$

This is the same as (69) in **122**. $I'$ being known, set the transit at $C$, run out the curve $CN$, and insert transition-curve in the usual way.

If $I'$ had been assumed in the beginning, $R'$ could be found from (194).

SECOND METHOD.—When the circular curve is flat, and short transition-curves are employed, we may compound the transition-curve with the circular at the $P.C._1$, taking care that the difference of curvatures is not greater than 1° or 2°.

Assume the position of the $P.C._1$ from 100 to 200 feet from the $P.C.$; measure the perpendicular let fall from the $P.C._1$ upon the tangent at the $P.C.$ produced; this will be $y_1$. The central angle $I_1$ can be calculated, knowing the length of circular curve from the $P.C.$ to the assumed $P.C._1$, or the angle between tangents may be measured with the transit. The coefficients $C$ and $E$ of (140) and (142) may be found from Table XIV with $I_1 = \phi$ as argument; then, from (140) and (142),

$$l_1 = \frac{y_1}{C}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (195)$$

$$x_1 = l_1(1 - E). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (196)$$

Measure back from the foot of the perpendicular let fall from the $P.C._1$ a distance $x_1$ along tangent, and set the $P.T.C.$

Intermediate points can be located, if needed, by offsets from tangent, computed by (140) or (170); thus at the mid-point the offset is $\frac{1}{8}y_1$.

THIRD METHOD.—From formula (170),

$$l_1 = \frac{y_1}{.005818 I_1{}^\circ},$$

and, from (36),
$$y_1 = \tfrac{7}{8} n^2 D.$$

Therefore
$$l_1 = \frac{.875 n^2 D}{.005818 I_1{}^\circ} = 150 \frac{n^2 D}{I_1{}^\circ}, \text{ nearly}$$

But $nD = I_1^\circ$; hence

$$l_1 = 150n\,; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (197)$$

and as $100n$ is the length of circular curve from $P.C.$ to $P.C._1$, *$l_1$ is once and a half as great.*

From (146),

$$D' = \frac{200I_1^\circ}{l_1} = \frac{200I_1^\circ}{150n} = \frac{200nD}{150n} = \frac{4}{3}D. \quad . \quad . \qquad (198)$$

From this equation it is seen that if the break in curvatures is limited to 2°, this method is admissible up to $D = 6^\circ$, independent of the length of transition-curve.

EXAMPLE.—A 4° curve is to have transition-curves inserted at each end; compute the necessary data.

BY FIRST METHOD.—Assume a 1.45-ft. offset, and the curvature to be changed from 4° to 5° by compounding. In Table I find $R = 1432.7$, $R' = 1146.3$; then, by (194),

$$\cos I' = 1 - \frac{1.45}{286.4} = .99494 = \cos 5^\circ\ 46'.$$

The length of 5° curve is $\frac{5.767}{5} = 1.153$ stations, and, by Table XVI, $I_1^\circ = 5^\circ$, so that the $P.C._1$ will fall 15.3 ft. back of the $P.C.C.$, while the $P.C.$ will be moved forward $\frac{5.767}{4} - 1.153 =$ .289 stations or 28.9 ft.; the $P.T.C.$ being, by Table XVI, 100 ft. back of the new $P.C.$ will fall $100 - 28.9 = 71.1$ ft. back of old $P.C.$ The transition-curve may now be located in the usual manner.

BY SECOND METHOD.—Assume the $P.C._1$ to fall 150 ft. from the $P.C.$, making $I_1^\circ = 1.5 \times 4 = 6^\circ$. From Table XIV, $C =$ .03488, and, by (36), $y_1 = \frac{7}{8}(1.5)^2 \times 4 = 7.875$ ft.

By (195),

$$l_1 = \frac{7.875}{.03488} = 225.8.$$

Now, by (146),

$$6 = \frac{D' \times 225.8}{200},$$

from which $D' = 5.314° = 5° \ 18.8'$, which differs less than 2° from $D$

By (196),

$$x_1 = 225.8(1 - .0011) = 225.6 \text{ ft.}$$

To find the position of *P.T.C.* with reference to the old *P.C.* consider that the distance from *P.C.* to foot of perpendicular from the $P.C._1$ is half the chord for angle $2I_1$, and can be taken from Table IX, being equal to $\frac{1}{2} \times \frac{1197.9}{4} = 149.7$. Then $225.6 - 149.7 = 75.9$ feet is the distance from old *P.C.* back to *P.T.C.*

By Third Method.—Assume the $P.C._1$ to be 150 ft. from the old *P.C.*; then, by (197), $l_1 = 225$ ft., and, by (198), the curvature of transition-curve at the $P.C._1$ is $\frac{4}{3} \times 4° = 5° \ 20'$, giving almost the same results as by the second method. Had we taken the $P.C._1$ 160 ft. from *P.C.* we should have had $l_1 = 240$, $D' = 5° \ 20'$; $x_1 = 239.7$, by interpolation from Table XVI; the length along tangent from *P.C.* to foot of perpendicular from $P.C._1$ 159.9 ft., and therefore $239.7 - 159.9 = 79.8$ ft. as the distance from *P.C.* to *P.T.C.*

## 161. To Insert Transition-curves at the *P.C.* and *P.C.C.* of a Compound Curve by Changing the Curvatures of the First Branch.

In Fig. 74 let *ABV* be the located curve compounding at *B*. Two cases occur.

First Case.—*Second branch having shorter radius.*

The offset at *P.C.C.* must be to outside of located curves; let it be $EB = F_2$ in the figure. Let $CP = F$ be known or assumed.

Draw the tangent *BG*, and draw *EH* parallel thereto. Let *CE* be the changed curve, and *CQ* parallel to tangent *AH*. Angle *I* may be computed from the known station numbers of *A* and *B*, or may be measured on the ground. The new tangent distance is $EQ = BG - GK - HQ$ (or *LS*). From the right triangle *GHK*, $GK = HK \tan GHK = F_2 \cot I$.

Similarly, $LS = LW \operatorname{cosec} I = F \operatorname{cosec} I$. Therefore

$$T \ = EQ = T - F_2 \cot I - F \operatorname{cosec} I. \quad . \quad . \quad (199)$$

*T* can be found from Table IX or formula (14); then *T'* is known from (199). The degree of new curve, *D'*, may now be found by means of Table IX, or from Table I by first finding

$R'$ by (15) The transition curve at the *P.C.C.* may be located by **146** and **151**, while that at the *P.C.* may be located either by offsets or deflections.

SECOND CASE.—*Second branch having longer radius.*

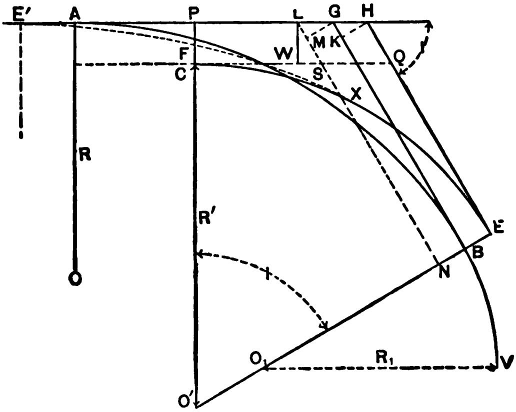


FIG. 74.

In this case the offset must be to inside of curve, and *NS* is the tangent required. From the figure, letting $NB = F_2$, $NS = T'$,

$$T' = T + F_2 \cot I - F \operatorname{cosec} I \quad . \quad . \quad . \quad . \quad (200)$$

The remainder of the solution is the same as for first case.

EXAMPLE.—A 5° curve compounds at sta. 280 with a 9° curve; the *P.C.* is at sta. 272. Required the change in curvature of first branch for an offset of 1.50 ft. at *P.C.C.* and 2.00 ft. at *P.C.*

Here $I = 8 \times 5° = 40°$, and, by (199),

$$T' = 417.1 - 1.5 \times 1.19175 - 2 \times 1.5557 = 412.2$$

$$D' = \frac{2085.5}{412.2} = 5.06° = 5° \; 3.6'.$$

$D_2 - D' = 9 - 5.06 = 3.94°$ is the difference in curvatures of the two branches of the altered curve. Entering Table XVI with this value for $D$ and $F = 1.5$ ft., we find:

for $l_1 = 220$, $F = 1.06 + .94(1.41 - 1.06) = 1.39$;
" $l_1 = 240$, $F = 1.26 + .94(1.67 - 1.26) = 1.65$.

$$\therefore \text{ for } F = 1.5,\ D = 3.94^\circ,\quad l_1 = 220 + 20\frac{1.5 - 1.39}{1.65 - 1.39} = 228.5$$

Bisect the offset at *P.C.C.*, measure 114.25 ft. along each curve, and set the ends of transition-curve. Midway between these points and *P.C.C.* offset $\frac{1}{16} \times 1.5 = 0.1$ ft.; these are all the points needed.

The length of transition-curve at *P.C.* may be found in like manner, taking $D = 5.06^\circ$ and $F = 2.0$ ft. as arguments in interpolating in Table XVI.

### 162. To Insert Transition-curves at the Ends of Two Circular Curves of Contrary Flexure united by a Common Tangent.

In Fig. 75 let the located line be *ABCE*; the tangent *BC* must be shifted outward at *B* and *C* to the position *HG*, the relative size of offsets being determined by the nature of the ground. The points *B'* and *C'* at which the tangents to circular curves will be parallel to *HG* will each move towards *S* a distance due to the increase of central angle, which increase equals $BSH = a$, for which we have

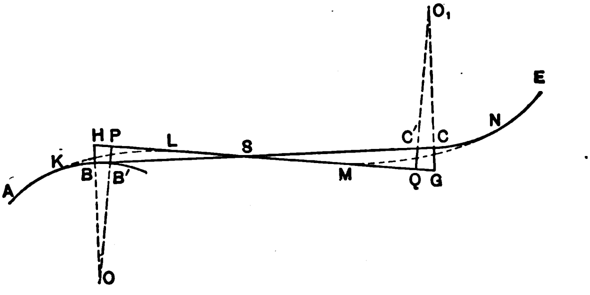


FIG. 75.

$$\tan a = \frac{BH + CG}{BC}. \quad \ldots\ldots \quad (201)$$

Let the offset at *B'* be *F*, and at *C'*, *F'*. Then

$$F = (R + BH)\cos a - R, \quad \ldots\ldots \quad (202)$$
$$F' = (R' + CG)\cos a - R'. \quad \ldots\ldots \quad (203)$$

*F* and *F'*, being now known, the transition-curves may be located.

**Example.**—A 6° curve and a 4° curve are united by a tangent 540 ft. long; *BH* for 6° curve = 4.5 ft.; *CG* for 4° curve = 3 ft.; *B* is at sta. 180, *C* at 185 + 40. Find *F* and *F'*.

By (201), $\tan a = \frac{7.5}{540} = .0139 = \tan 0° 48'$.

*B* will be moved forward $\frac{.8}{6} = .133$ stas. = 13.3 ft. to sta. 180 + 13.3, and *C* will be moved backwards $\frac{.8}{4} = .2$ stas. or 20 ft. to 185 + 20.

By (202), $F = (955.4 + 4.5)0.99990 - 955.4 = 4.4$ ft.

By (203), $F' = (1432.7 + 3)0.99990 - 1432.7 = 2.86$ ft.

These values call for $l_1 = 317.8$ ft. for 6° curve, and $l_1 = 313.3$ for 4° curve.

**Remark.**—It will frequently be found that this problem allows the line to be thrown on better ground. Should the ground require tangent to be shifted inward, the curves must be sharpened by compounding to admit of the necessary offsets.

### 163. Having Run a Tangent which Falls Outside a Located Curve, to Find the Offset *F* for a Transition-curve Uniting them.

In Fig. 76 let the tangent be *AB*; *CE* the located curve. Set transit at some point *C*, and bring telescope into tangent to curve. Measure *CB* and move to *B*, where angle *ABC* must be measured; or measure *CH* perpendicular to *AB*; then

$$\sin a = \frac{CH}{CB}.$$

Now $EG = R \text{ vers } a$; or it is the mid-ordinate for twice *a*, and may be found from Table IX; then

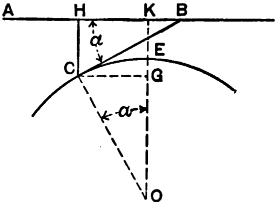


FIG. 76.

$$F = CH - EG = CH - R \text{ vers } a. \quad . \quad . \quad . \quad (204)$$

The point *E* is found from *C* by the relation $EC = \frac{a}{D}$.

The transition-curve may now be located.

**164. Inserting Transition-curves in Old Track.**—Sections **159** and **160** afford the means of inserting transition-curves, of which **159** is theoretically the best, though from the amount of track disturbed it may be better to employ **160.** Sometimes the method of **162** may be employed to advantage when the connecting tangent is short. For easing the curves at point of compounding, the method of **161** may be made use of.

The offsets must necessarily be small if the new track is required to occupy the old road-bed. It may be profitable to add to the road-bed when sufficient offset cannot be secured for sharp curves, though ordinarily much good can be accomplished even when the new track is restricted to the old road-bed.

Unless the theoretical *P.C.*, *P.C.C.*, and *P.T.* have been marked by monuments it may be difficult to retrace the old lines. If there is plenty of room, the terminal tangents may be prolonged to intersection and *I* measured, after which the degree of curve may be found by measuring around curve and by approximate measurements of the tangent distances; then one or two assumptions and computations will generally suffice.

In cuts and rough country the curve may be run out by setting transit in center of road-bed and measuring the deflection-angles for a few points around the curve.

After the transition-curves have been inserted permanent monuments should be placed at each end of transition-curve to guide the trackman in keeping up the proper superelevation of outer rail.

**165. Remarks on Tabular Interpolations.**—The general interpolation formula given in algebra is

$$t = a + pd_1 + \frac{p(p-1)}{2!}d_2 + \frac{p(p-1)(p-2)}{3!}d_3 + \frac{p(p-1)(p-2)(p-3)}{4!}d_4 + \text{etc.},$$

in which $t$ is any term, $a$ the first term taken, $p$ the number of terms from $a$ to $t$, $d_1$ the first from $a$ of the first order of differences, $d_2$ the first of the second order of differences, etc.

In ordinary linear interpolation all terms after the second are neglected; in interpolating by second differences all after the third, etc.

In Table XIV linear interpolation will answer for *C* and ordinarily for *E*, though second differences may sometimes be needed for the latter.

In Table XV, *A* is a quadratic function of *n*, as shown by formula (153), while *B* is a cubic function of that portion that has been retained. Hence *A* should be interpolated by second differences, while theoretically *B* should be interpolated by third differences; but as *B* is always quite small, its second and third differences will be too small to affect results, and linear interpolations may be made when any are needed.

In Table XVI linear interpolations will generally suffice, though when *F* and *y* are large it may be necessary to use second differences.

The examples of **158** and **161** illustrate the method of interpolating in Table XVI for intermediate values of *F* and *D*. Values of *F* were first found for the given degree of curve and assumed values of $l_1$, so taken that the true $l_1$ should be between them. From these assumed values of $l_1$ and *F*, taken with the required *F*, the true $l_1$ was found by linear interpolation.

As an extreme case suppose *F* and $y_1$ wanted for an 18° curve when $l_1 = 408$ feet.

First write a few values of $y_1$ and *F* so as to obtain the first and second differences.

| $l_1$ | $y_1$ | $d_1$ | $d_2$ | $F$ | $d_1$ | $d_2$ |
|---|---|---|---|---|---|---|
| 400 | 81.43 | | | 20.63 | | |
| | | 8.08 | | | 2.08 | |
| 420 | 89.51 | | 0.35 | 22.71 | | 0.10 |
| | | 8.43 | | | 2.18 | |
| 440 | 97.94 | | 0.35 | 24.89 | | 0.10 |
| | | 8.78 | | | 2.28 | |
| 460 | 106.72 | | | 27.17 | | |

By the interpolation formula, when $l_1 = 408$,

$$y_1 = 81.43 + \tfrac{8}{20} \times 8.08 + \frac{\frac{8}{20}(\frac{8}{20} - 1)}{2} \times 0.35 = 84.62,$$

$$F = 20.63 + \tfrac{8}{20} \times 2.08 + \frac{\frac{8}{20}(\frac{8}{20} - 1)}{2} \times 0.10 = 21.45.$$

By linear interpolation, $y_1 = 84.66$, $F = 21.46$.

Again, suppose $y_1$ to be wanted when $l_1 = 430$. By the formula,

$$y_1 = 81.43 + \tfrac{30}{20} \times 8.08 + \frac{\frac{30}{20}(\frac{30}{20} - 1)}{2} \times 0.35 = 93.68,$$

or

$$y_1 = 89.51 + \tfrac{10}{20} \times 8.43 + \frac{\frac{10}{20}(\frac{10}{20} - 1)}{2} \times 0.35 = 93.68.$$

# CHAPTER V.

## *TURNOUTS, FROGS, AND SWITCHES.*

### ARTICLE 14. TURNOUTS.

### *A. Turnouts from Straight Lines.*

**166. A Turnout** is a track leading from one track to another, and is made up of a switch, a frog and the rails necessary to connect these and to extend the turnout beyond the frog-point.

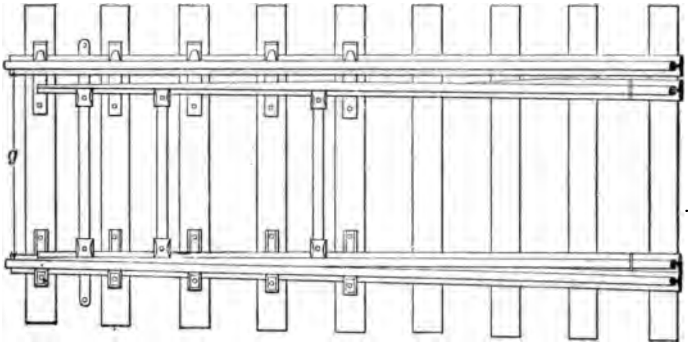
*a.* **The Gauge Lines** of a track coincide with the inside faces of the rail heads on a line $\frac{5}{8}$ inch below the top of rails.

*b.* **The Gauge,** *g,* of a track is the distance between gauge lines of that track, and for standard gauge track equals 4 feet $8\frac{1}{2}$ inches on tangents. To accommodate rigid wheel-bases of trucks, the gauge is increased on curves, and should be greater for sharp curves than for flat ones.

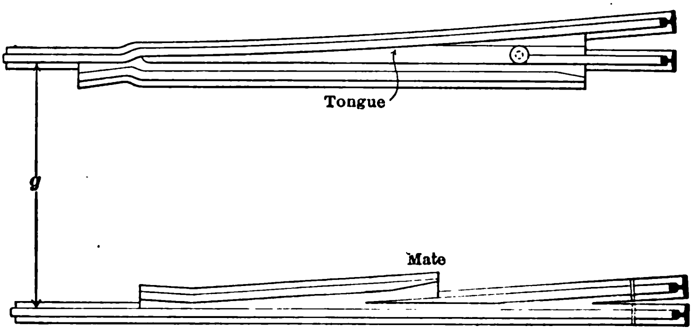
*c.* **The Switch-rails** (or **Switch-points**) are two wedge-shaped sections yoked together by bridle-bars or rods and free to slide on plates which rest on the *switch-ties.* The *point of switch* is that point at which the turnout begins, and for split switches—the form used on all steam roads except for a comparatively few unimportant spurs or sidings—is movable by means of a *switch-stand,* or by an interlocking system operated from a suitable tower. The *heel* of switch is the other end of the switch-rail, and is fixed in position, but not so firmly as to prevent free movement of the rest of the switch rail when the switch is thrown. The theoretical and actual points of switch do not coincide, but the point is "dubbed off" where its thickness reduces to about $\frac{1}{4}$ inch. The usual lengths of switch-rails are either 15 or $16\frac{1}{2}$ feet, though longer ones are now coming into more general use than heretofore.

In Fig. 77 (*a*) represents the Split Switch, (*b*) the Tongue-and-mate Switch, and (*c*) the Stub Switch.

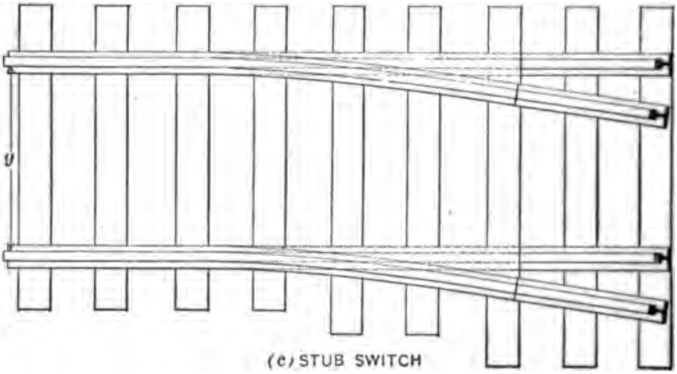
The Tongue-and-mate Switch is composed of a steel wedge or tongue as one rail, pivoted at its heel and moving in a cast-iron frame around which a street pavement may be built. In the opposite rail is a rigid fitting, called a mate, in the



(a) SPLIT SWITCH



(b) TONGUE AND MATE SWITCH



(c) STUB SWITCH

Fig. 77.

arrangement employed by street railways, but when used by steam roads it consists usually of a pair of tongues only, operated in the same manner as a split switch.

In a *Stub Switch* the toe is fixed and the heel moves. A full length rail is spiked for part of its length, the remainder being free to move by sliding on plates on the ties, the pair of sliding rails being yoked together so that both move at the same time. This type of switch should never be used on standard track, but may be used during construction, and in places where cheap installation is important and danger of derailment is small.

*d.* **The Throw,** *t*, is the distance through which the point of switch moves at right angles to the track from which the turnout leads and is usually about 5½ or 5¾ inches. The heel distance, *h*, need not be greater than this, but, to allow room for fastening the ends of the point rails, is usually 6 or 6½ inches. The switch stand, or operating device in case of an interlocking system, rests upon one or two extra long ties termed the *Head Block,* which should be set, whenever possible, upon that side of the track which is on the engineman's side of the cab as the train approaches the turnout.

*e.* **A Switch Stand** is set opposite the point ends of switch-rails upon the head block and carries a lever which operates the rods connecting to the switch-rails, and at the same time moves the target to indicate to the engineman whether the switch is set for the main line or the siding. At night colored lights serve the same purpose as the target serves during daylight. For interlocking systems signals are shown by semaphores.

In order to limit the number of obstructions in crowded yards, various devices, such as the *Tumbling-lever* stand, or *Ground-lever* stand, the *Monkey-switch,* etc., are frequently used.

A *Facing Point* switch, or simply a *Facing* switch, is one for which the normal direction of traffic on a double track railway is from the switch-points towards the frog, and a *Trailing* switch is one for which the normal direction of traffic is from the frog towards the switch-points. In the interests of safety the latter arrangement should always be used if it be possible to do so.

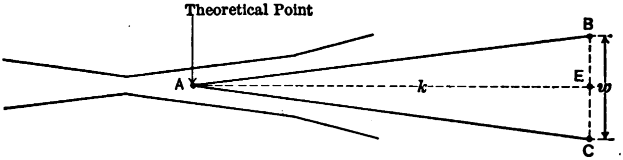
On single track all switches are facing or trailing switches, according to the direction of traffic.

*f*. **The Frog-point** is situated at the intersection of the gauge lines of the intersecting rails and lies a few inches in advance of the actual blunt point as the frog is manufactured. The thickness of the actual point is about ½ inch.

*g*. **A Guard Rail** is set on the inside of the rail opposite to that in which the frog is located, in order to guide the wheel-flanges in the proper direction. This is a section of rail, having its ends bent, and set far enough from the track rail to give clearance for wheel-flanges.

*h*. **The Frog-angle,** *F*, is the angle at the theoretical frog-point between the gauge lines of the frog.

*i*. **The Frog Number,** *N*, is the ratio of the axial length, measured from the theoretical frog-point, to the width of base as measured at right angles to the axial length.



DIAGRAMATIC FROG

FIG. 78.

Fig. 78 is a diagrammatic representation of a frog. By definition

$$N=\frac{AE}{BC}=\frac{k}{w},$$

and also

$$\text{Cot}\,\tfrac{1}{2}F=\frac{k}{\frac{1}{2}w}=2N, \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (205)$$

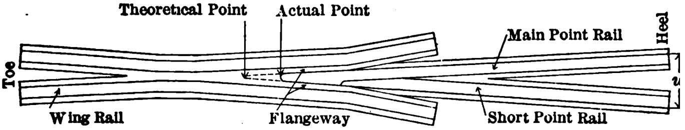
$$\text{Tan}\,\tfrac{1}{2}F=\frac{1}{2}\,\frac{w}{k}=\frac{1}{2N}. \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (206)$$

*j*. **The Lead,** *l*, is the distance from the point of switch to the theoretical point of frog, and *L* the distance from point of switch to actual point of frog, measured along the main rail in which the frog is placed. In Fig. 80 $CB=l$ and $CP=L$.

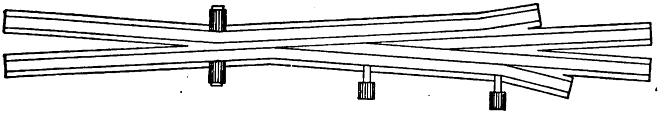
*k*. **The Frog Distance,** *f. d.*, is the length of chord of outer rail of turnout measured from the heel of switch to toe of frog (end of wing rail) for straight switch-points and frogs, and from the theoretic point of switch-rail to theoretic point of frog if the switch-rails are regarded as curved and the turnout curve tangent to the frog at its theoretic point. In Fig. 80, *HM* is the frog-distance for the first case, and in Fig. 92 *AB* is the frog-distance for the second case.

*l.* **The Stub Lead,** *s. l.*, is the distance measured along main rail from the actual point of frog to a point where the turnout rail diverges from the main rail a distance equal to the throw. In Fig. 80 $CP = l$ and $QP = s.\ l.$

*m.* **Frogs** are constructed either as *Rigid Frogs*, that is, those having their several parts fixed in relation to each other by rivetting to a bottom plate, or as *Spring-rail Frogs*, for which the point is normally held against the main rail, so as to avoid the gap which is present in rigid frogs, and which must be sprung by the wheel-flange when a train is passing the frog on the turnout. In Fig. 79 (*a*) shows the arrangement of the rigid frog and (*b*) that of the spring frog.



(*a*) RIGID FROG



(*b*) SPRING RAIL FROG

FIG. 79.

**167. Given the Frog-number, *N*, the Gauge, *g*, the Length of Switch-rail, *s*, the Distance from the Theoretical Point to Toe of Frog, *f*, and the Width or Thickness of Frog-point, *w′*, to Find the Radius, *R*, of Center Line of Turnout and the Leads *l* and *L* from *C* to *B* and *C* to *P*, respectively, in Fig. 80.**

Fig. 80 shows the notation employed.

From the triangle *AXH*,

$$\sin S = \frac{h}{s}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (207)$$

From triangle $BVM$,

$$m = f \text{ cosin } F, \quad \text{and} \quad n = f \sin F. \quad . \quad . \quad . \quad . \quad . \quad (a)$$

In formula (207) $h$ = actual heel distance − thickness of switch-rail point.

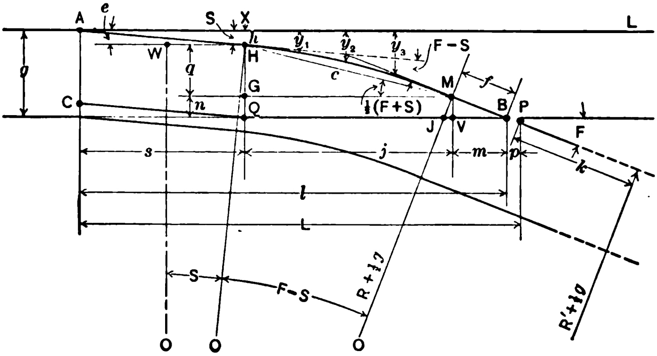


FIG. 80.

In triangle $MGH$, $q = g - h - n$, and

$$HM = c = q \operatorname{cosec} \tfrac{1}{2}(F+S) = \frac{q}{\sin \frac{1}{2}(F+S)}. \quad . \quad . \quad (b)$$

Also,

$$GM = j = q \operatorname{cotan} \tfrac{1}{2}(F+S) = \frac{q}{\tan \frac{1}{2}(F+S)}. \quad . \quad . \quad (c)$$

From triangle $HMO$,

$$R + \tfrac{1}{2}g = \frac{c}{2 \sin \frac{1}{2}(F-S)} = \tfrac{1}{2}c \operatorname{cosec} \tfrac{1}{2}(F-S). \quad . \quad . \quad (208)$$

At the frog-point,

$$p = \frac{\frac{1}{2}w'}{\sin \frac{1}{2}F} = \tfrac{1}{2}w' \operatorname{cosec} \tfrac{1}{2}F. \quad . \quad . \quad . \quad . \quad . \quad . \quad (d)$$

From the figure,

$$l = s + j + m, \quad \text{and} \quad L = s + j + m + p. \quad . \quad . \quad (209)$$

In the formulas for $c$ and $q$, $g$ and $h$ must be reduced by the thickness of switch-rail point before solving.

**168. The Coordinates to the Quarter-points of the Lead-rail, $HM$,** may be found as follows:

Produce the curve $MH$ backward to $W$, where its tangent will be parallel to main line track. The intercept between $W$ and the foot of a perpendicular let fall from $H$ upon $OW$ is $=(R+\frac{1}{2}g)(1-\cos S)=(R+\frac{1}{2}g)\operatorname{vers} S$, and therefore

$$e=h-(R+\tfrac{1}{2}g)\operatorname{vers} S \quad . \quad . \quad . \quad . \quad . \qquad (210)$$

The offset from the quarter-point of lead-rail is

$$\left.\begin{aligned} y_1&=e+(R+\tfrac{1}{2}g)\operatorname{vers}[S+\tfrac{1}{4}(F-S)]\\ &=e+(R+\tfrac{1}{2}g)\operatorname{vers}\tfrac{1}{4}(F+3S)\\ x_1&=s+(R+\tfrac{1}{2}g)[\sin(S+\tfrac{1}{4}(F-S))-\sin S]\\ &=s+(R+\tfrac{1}{2}g)[\sin\tfrac{1}{4}(F+3S)-\sin S]\end{aligned}\right\} \quad . \qquad (211)$$

For the mid-point

$$\left.\begin{aligned} y_2&=e+(R+\tfrac{1}{2}g)\operatorname{vers}[S+\tfrac{1}{2}(F-S)]\\ &=e+(R+\tfrac{1}{2}g)\operatorname{vers}\tfrac{1}{2}(F+S)\\ x_2&=s+(R+\tfrac{1}{2}g)[\sin\tfrac{1}{2}(F+S)-\sin S]\end{aligned}\right\} \quad . \qquad (212)$$

For the three-quarter-point

$$\left.\begin{aligned} y_3&=e+(R+\tfrac{1}{2}g)\operatorname{vers}[S+\tfrac{3}{4}(F-S)]\\ &=e+(R+\tfrac{1}{2}g)\operatorname{vers}\tfrac{1}{4}(3F+S)\\ x_3&=s+(R+\tfrac{1}{2}g)[\sin\tfrac{1}{4}(3F+S)-\sin S]\end{aligned}\right\} \quad . \qquad (213)$$

**169. The Closures, $HM$, of Curved Track, and $QJ$, of Straight Track, between Heels of Switch-rails and Toes of Frog,** may readily be found from Fig. 80, as follows:

$$HM=(R+\tfrac{1}{2}g)\operatorname{arc}(F-S). \quad . \quad . \quad . \quad . \qquad (214)$$

In which arc $(F-S)$ is the angle $HOM$ reduced to circular measure.

If the wing rails $JB$ and $MB$ of frog are of equal length the closure for straight rail is

$$QJ=L-(s+f+p)=l-(s+f). \quad . \quad . \quad . \qquad (215)$$

From (214) and (215)

$$\begin{aligned} HM-QJ&=(R+\tfrac{1}{2}g)\operatorname{arc}(F-S)-L+s+f+p,\\ &=(R+\tfrac{1}{2}g)\operatorname{arc}(F-S)+f-j-m, \quad . \quad . \qquad (216)\end{aligned}$$

Fig. 80 yields also the following value of this difference:

$$HM-QJ=(R+\tfrac{1}{2}g)[\operatorname{arc}(F-S)+\sin S-\sin F]. \quad . \qquad (216')$$

If the wing rails of the frog are so made that the difference of their lengths equals the above difference, the two closures will be equal. This will require that both right- and left-hand frogs be carried in stock, however.

**170. Practical Leads.** To avoid having to cut rails in order to make the closures *HM* and *QJ*, called for by Equations (214) and (215), it is customary to modify these so that available standard lengths may be used. This modification deforms the curve between *H* and *M* somewhat, but as trains should be moving slowly when entering or leaving turnouts, this change is not material.

A further desirable modification, suggested by equations (216) and (216′), is to have the toe length, *f*, of the frog on the turnout side made longer than that on the main-rail side in order that the arc *HM* may just equal the main-line closure which takes the place of *QJ*.

Most of the larger railroad systems have their own standard turnouts for which the necessary functions and dimensions are worked out and tabulated in the office for the various frog-numbers used by each system. The foreman of the track gang then needs only to have the locations of the actual frog points marked on the ground by the engineers, though it is desirable to have the head-blocks marked also by stakes.

Whenever possible the frog should be so located that its heel on the main-line will fall at a rail joint in order to avoid having to cut a rail. This can generally be done by shifting the point of frog forward or backward a few feet, and at the same time hold the turnout curve upon the previously prepared road bed. The radius of turnout curve and the offsets to its outer rail will, however, be changed.

### 171. To Find the Increase of Tangent beyond Heel of Switch-rail, and New Radius of Outer Rail for a Given Increase in the Lead.

In Fig. 81 *AHMB* represents outer rail of turn out as computed by the preceding methods; *A′NH′MB* the transformed turnout required by the practical lead $C'B = L'$. *NH′* is required.

Let *HN* be parallel to main rail. *H*, *H′*, and *M* lie on the same straight line, since the central angles of the curves ***HM*** and $H'M$ are equal. In triangle $NHH'$ the angle at $H$ equals $180° - \frac{1}{2}(F+S)$ and $NH = A'A = C'C$.

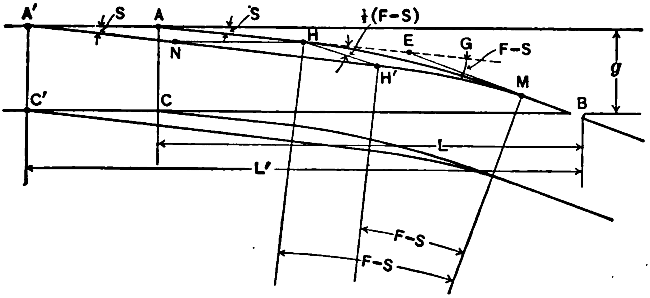


FIG. 81.

$$\therefore \; NH' = \frac{A'A \sin \frac{1}{2}(F+S)}{\sin \frac{1}{2}(F-S)} = s' - s. \quad . \quad . \quad . \quad (217)$$

Also,

$$HH' = \frac{A'A \sin S}{\sin \frac{1}{2}(F-S)},$$

and

$$H'M = c' = c - HH'.$$

The radius of the transformed curve will now be given by

$$R' = \frac{c'}{2 \sin \frac{1}{2}(F-S)} - \frac{1}{2}g. \quad . \quad . \quad . \quad . \quad (218)$$

For the offsets at the quarter-points, formulas (211), (212), and (213) will apply if for $e$, as determined by (210), we substitute,

$$e = h + (s' - s) \sin S - (R' + \frac{1}{2}g) \operatorname{vers} S.$$

**172. To Find the Increase of Tangent Past the Toe of Frog and the Radius of Outer Rail for a Given Decrease in the Lead.**

In Fig. 82 $AHMB$ represents the outer turnout rail as computed where the theoretic lead is used; $A'H'M'B$ the transformed curve required by the change $CC' = AA'$ of lead. $NM'$ and $HH'$ are parallel and equal to $AA'$, since the chords $HM$ and $H'M'$ are parallel. From triangle $NM'M$.

$$MM'=\frac{AA'\sin\frac{1}{2}(F+S)}{\sin\frac{1}{2}(F-S)}. \quad . \quad . \quad . \quad . \quad (219)$$

Also,

$$NM=\frac{AA'\sin F}{\sin\frac{1}{2}(F-S)},$$

and

$$H'M'=HN=c'=c-NM.$$

$$\therefore\ R' = \frac{c'}{2\sin\frac{1}{2}(F-S)}-\tfrac{1}{2}g. \quad . \quad . \quad . \quad . \quad (220)$$

For the offsets at quarter-points, formulas (211), (212), and (213) will apply by making $e=h+M'M\sin F-(R'+\frac{1}{2}g)\operatorname{vers} S$.

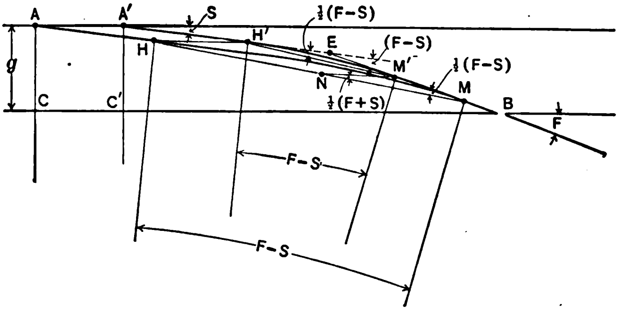


FIG. 82.

**173. Tables of Theoretical and Practical Leads,** as recommended by the American Railway Engineering Association, are given below. The thickness of all frog-points is taken as ½ inch, and of all switch-points ¼ inch. The "Frog Bluntness" is $p$, of Fig. 80, and equals ½ inch multiplied by the frog number. The heel distance, $h$, is taken as 6¼ inches in all cases. The length of wing rail from the theoretical point of frog to its toe varies in practice with the standards adopted by different manufacturers or the requirements of particular railway systems, as does also the total length of frog. The values given in the first table are those recommended by the Association, based on theoretical computations, and the values in the second table are those which the Association recommends for practical use as involving a minimum of rail cutting.

## TABLE OF THEORETICAL SWITCH-LEADS FOR STRAIGHT FROGS AND SWITCH-RAILS.

| Frog Number. *N* | Frog Bluntness. *p* | Frog Angle. *F* | | | Length of Wing from Point to Toe of Frog. *f* | | Length of Frog from Theoretical Point to Heel. | | Total Length, Toe to Heel. | | Spread at Toe. | Spread at Heel. *w* | Length of Switch-rail. *s* | | Switch-rail Angle. *S* | | | Radius of Center Line of Turnout. *R* | Degree of Turnout Curve. *D* | | | Theoretical Lead to Theoretical Frog-point. *l* | Theoretical Lead from Head Block to Actual Frog-point. *L* | Closure for Straight Rail. *QJ* | Closure for Curved Rail *HM* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ft. | ° | ′ | ″ | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | Ft. | Ft. | In. | ° | ′ | ″ | Ft. | ° | ′ | ″ | Ft. | Ft. | Ft. | Ft. |
| 4 | 0.17 | 14 | 15 | 00 | 3 | 2 | 5 | 4 | 8 | 6 | 0.79 | 1.32 | 11 | 0 | 2 | 36 | 19 | 112.26 | 52 | 53 | 56 | 37.05 | 37.22 | 22.88 | 23.29 |
| 5 | 0.21 | 11 | 25 | 16 | 3 | 7 | 6 | 5 | 10 | 0 | 0.71 | 1.28 | 11 | 0 | 2 | 36 | 19 | 183.22 | 31 | 40 | 24 | 42.77 | 42.98 | 28.19 | 28.55 |
| 6 | 0.25 | 9 | 31 | 38 | 4 | 0 | 7 | 0 | 11 | 0 | 0.66 | 1.16 | 11 | 0 | 2 | 36 | 19 | 273.95 | 21 | 01 | 58 | 48.11 | 48.36 | 33.11 | 33.38 |
| 7 | 0.29 | 8 | 10 | 16 | 4 | 5 | 8 | 1 | 12 | 6 | 0.63 | 1.15 | 16 | 6 | 1 | 44 | 11 | 364.88 | 15 | 47 | 19 | 61.94 | 62.23 | 41.02 | 41.24 |
| 8 | 0.33 | 7 | 09 | 10 | 4 | 9 | 8 | 9 | 13 | 6 | 0.59 | 1.09 | 16 | 6 | 1 | 44 | 11 | 488.71 | 11 | 44 | 40 | 67.47 | 67.80 | 46.22 | 46.42 |
| 9 | 0.37 | 6 | 21 | 35 | 6 | 0 | 10 | 0 | 16 | 0 | 0.67 | 1.11 | 16 | 6 | 1 | 44 | 11 | 616.27 | 9 | 18 | 27 | 72.24 | 72.61 | 49.74 | 49.92 |
| 9½ | 0.40 | 6 | 01 | 32 | 6 | 0 | 10 | 0 | 16 | 0 | 0.63 | 1.05 | 16 | 6 | 1 | 44 | 11 | 699.97 | 8 | 11 | 33 | 74.90 | 75.30 | 52.40 | 52.58 |
| 10 | 0.42 | 5 | 43 | 29 | 6 | 0 | 10 | 6 | 16 | 6 | 0.60 | 1.05 | 16 | 6 | 1 | 44 | 11 | 790.25 | 7 | 15 | 18 | 77.51 | 77.93 | 55.01 | 55.17 |
| 11 | 0.46 | 5 | 12 | 18 | 6 | 0 | 11 | 6 | 17 | 6 | 0.54 | 1.05 | 22 | 0 | 1 | 18 | 08 | 940.21 | 6 | 05 | 48 | 92.06 | 92.52 | 64.06 | 64.20 |
| 12 | 0.50 | 4 | 46 | 19 | 6 | 5 | 12 | 1 | 18 | 6 | 0.53 | 1.01 | 22 | 0 | 1 | 18 | 08 | 1136.34 | 5 | 02 | 38 | 97.25 | 97.75 | 68.83 | 68.96 |
| 15 | 0.62 | 3 | 49 | 06 | 7 | 8 | 14 | 10 | 22 | 6 | 0.51 | 0.99 | 33 | 0 | 0 | 52 | 05 | 1744.38 | 3 | 17 | 01 | 123.02 | 133.64 | 92.36 | 92.46 |
| 16 | 0.67 | 3 | 34 | 47 | 8 | 0 | 16 | 0 | 24 | 0 | 0.50 | 1.00 | 33 | 0 | 0 | 52 | 05 | 2005.98 | 2 | 51 | 24 | 135.95 | 136.62 | 94.95 | 95.05 |
| 18 | 0.75 | 3 | 10 | 56 | 8 | 10 | 17 | 8 | 26 | 6 | 0.49 | 0.98 | 33 | 0 | 0 | 52 | 05 | 2587.66 | 2 | 12 | 52 | 146.38 | 147.13 | 104.54 | 104.61 |
| 20 | 0.83 | 2 | 51 | 51 | 9 | 8 | 19 | 4 | 29 | 0 | 0.48 | 0.97 | 33 | 0 | 0 | 52 | 05 | 3262.98 | 1 | 45 | 22 | 156.35 | 157.18 | 113.68 | 113.76 |
| 24 | 1.00 | 2 | 23 | 13 | 11 | 4 | 23 | 2 | 34 | 6 | 0.47 | 0.97 | 33 | 0 | 0 | 52 | 05 | 4932.77 | 1 | 09 | 42 | 175.09 | 176.09 | 130.66 | 130.77 |

## TABLE OF PRACTICAL SWITCH-LEADS FOR STRAIGHT FROGS AND SWITCH-RAILS

| Frog Number. | Radius of Center Line. | Degree of Turnout Curve. | Rectangular Co-ordinates to the Quarter and Center Points on Gauge Side of Curved Rail, Referred to Point of Switch-rail as Origin. | | | | | | Tangent Adjacent to Switch-rail. | Tangent Adjacent to Toe of Frog. | Distance from Actual Point of Switch-rail to Theoretical Frog-point. | Distance from Actual Point of Switch-rail To Actual Frog-point | Closure for Straight Rail. | Closure for Curved Rail. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N$ | $R$ | $D$ | $x_1$ | $y_1$ | $x_2$ | $y_2$ | $x_3$ | $y_3$ | $HH'$ | $MM'$ | $l'$ | $L'$ | | |
| | Ft. | ° ′ ″ | Ft. | Ft. | Ft. | Ft. | Ft. | Ft. | Ft. | Ft. | Ft. | Ft. | | |
| 4 | 110.69 | 53 42 24 | 17.74 | 0.97 | 23.44 | 1.67 | 29.75 | 2.79 | 1.03 | 0.00 | 37.77 | 37.94 | 23.60 | 24 |
| 5 | 174.34 | 33 19 57 | 17.78 | 0.95 | 24.54 | 1.61 | 31.27 | 2.62 | 0.00 | 0.82 | 42.26 | 42.47 | 27.68 | 28 |
| 6 | 265.39 | 21 43 04 | 19.07 | 1.01 | 27.13 | 1.74 | 35.15 | 2.72 | 0.00 | 0.66 | 47.73 | 47.98 | 32.73 | 33 |
| 7 | 362.08 | 15 52 29 | 26.72 | 0.97 | 36.93 | 1.71 | 47.11 | 2.74 | 0.00 | 0.19 | 61.81 | 62.10 | 13.89+27 | 14.11+27 |
| 8 | 487.48 | 11 46 27 | 28.37 | 1.02 | 39.91 | 1.78 | 51.45 | 2.91 | 0.30 | 0.00 | 67.65 | 67.98 | 16.40+30 | 16.60+30 |
| 9 | 605.18 | 9 28 42 | 28.75 | 1.02 | 40.98 | 1.76 | 53.19 | 2.75 | 0.00 | 0.57 | 71.91 | 72.28 | 16.41+33 | 16.59+33 |
| 9½ | 695.45 | 8 14 45 | 30.31 | 1.06 | 43.35 | 1.82 | 56.37 | 2.83 | 0.76 | 0.00 | 75.32 | 75.71 | 25.82+27 | 26.00+27 |
| 10 | 790.25 | 7 15 18 | 30.28 | 1.06 | 44.05 | 1.84 | 57.81 | 2.85 | 0.00 | 0.00 | 77.51 | 77.93 | 27.00+28 | 27.17+28 |
| 11 | 922.65 | 6 12 47 | 40.74 | 1.08 | 56.47 | 1.84 | 72.19 | 2.87 | 2.99 | 0.00 | 93.85 | 94.31 | 32.85+33 | 2×33 |
| 12 | 1098.73 | 5 12 59 | 43.99 | 1.15 | 60.65 | 1.90 | 77.28 | 2.91 | 5.33 | 0.00 | 100.30 | 100.80 | 23.88+2×24 | 3×24 |
| 15 | 1744.38 | 3 17 01 | 55.49 | 1.01 | 77.95 | 1.78 | 100.41 | 2.85 | 0.00 | 0.00 | 132.66 | 133.28 | 25.90+2×33 | 26.00+2×33 |
| 16 | 1993.24 | 2 52 59 | 58.16 | 1.04 | 81.76 | 1.82 | 105.35 | 2.87 | 1.56 | 0.00 | 136.90 | 137.57 | 29.90+2×33 | 30.00+2×33 |
| 18 | 2546.31 | 2 14 31 | 58.73 | 1.04 | 84.46 | 1.82 | 110.10 | 2.86 | 0.00 | 1.08 | 145.76 | 146.51 | 25.93+3×26 | 4×26 |
| 20 | 3257.26 | 1 45 32 | 61.84 | 1.08 | 90.21 | 1.88 | 118.59 | 2.93 | 0.44 | 0.00 | 156.59 | 157.42 | 26.92+2×27 +33 | 33.00+3×27 |
| 24 | 4886.16 | 1 10 21 | 67.82 | 1.27 | 100.21 | 1.97 | 132.59 | 3.00 | 2.43 | 0.00 | 176.22 | 177.22 | 32.89+3×33 | 4×33 |

The tendency now is toward the use of frogs of smaller angles, and, therefore, larger values of $N$, than was the practice some years ago. A No. 10 frog on main line is now the standard on many systems which a few years ago used No. 9, or even No. 8 frogs under the same conditions. In railroad yards frogs of smaller number than those required on main lines may be admissible in cases where available space is limited, but for important terminals it is well to make No. 9 or No. 10 the minimum. For minor yards Nos. 8, 7½ or even 7 may have to be used except where modern yard engines of long wheel-bases are employed.

**174. Ordinates from the Long Chord to the Center and Quarter-points of Outer Rail of Turnout** may be used in staking out the curve instead of using the coordinates referred to the point of switch-rail. The length, $c$, of the chord $HM$ of Fig. 80 having been computed by (b) of Section **167**, these ordinates may be computed by one of the methods given in Section **83**. The table below gives these values of the ordinates for the turnouts corresponding to the frog-numbers given in the tables of the preceding section.

TABLE OF ORDINATES OF CURVED RAIL.

| Frog Number. | CENTER. | | Quarter Points. | |
|---|---|---|---|---|
| | Feet. | Inches. | Feet. | Inches. |
| **4** | 0.59 | 7⅛ | 0.44 | 5⅜ |
| **5** | 0.55 | 6⅝ | 0.41 | 5 |
| **6** | 0.50 | 6 | 0.38 | 4½ |
| **7** | 0.58 | 7 | 0.43 | 5¼ |
| **8** | 0.58 | 6⅝ | 0.41 | 5 |
| **9** | 0.50 | 6 | 0.38 | 4½ |
| **9½** | 0.49 | 5⅞ | 0.37 | 4⅜ |
| **10** | 0.48 | 5¾ | 0.36 | 4⅜ |
| **11** | 0.55 | 6⅝ | 0.41 | 4⅞ |
| **12** | 0.52 | 6¼ | 0.39 | 4¾ |
| **15** | 0.58 | 7 | 0.43 | 5¼ |
| **16** | 0.56 | 6¾ | 0.42 | 5 |
| **18** | 0.53 | 6⅜ | 0.40 | 4¾ |
| **20** | 0.50 | 6 | 0.37 | 4½ |
| **24** | 0.44 | 5⅜ | 0.33 | 4 |

**175. The Frog Tangent,** $k$.—In order to connect the turnout curve with a diverging branch-track, or with a parallel siding, a curve is required beyond the frog. Because of the ease with which the required functions may be computed, this curve is frequently assumed to begin at the frog-point, but since standard frogs are manufactured with tangent lines from toe to heel, this method is incorrect. The distortion is greater with spring than with rigid frogs, because the tangent lines of the former are longer.

The *P.C.* of the curve beyond frog may begin at the heel of frog, but it is better practice to continue the tangent line for a rail length or more beyond the heel, especially if road engines having long wheel-bases must use the turnout, as will occur at "Y's" and the junctions of main and branch lines. The distance from actual point of frog to the *P.C.* is called the *frog-tangent.*

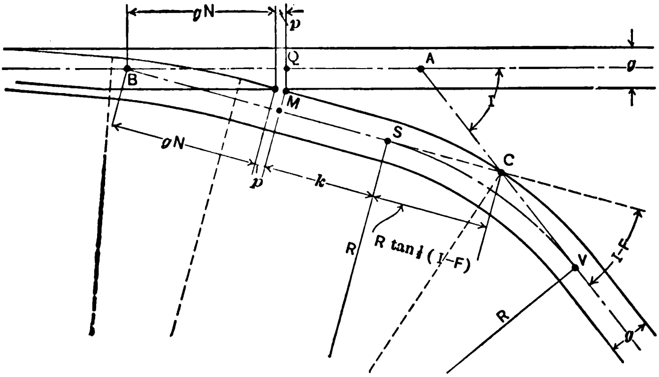


FIG. 83.

**176. The Field Work for Locating a Turnout from Straight Main Line** consists, after having the frog-point and head block located, of the following steps:

First find, in Fig. 83,

$$QB = MB = \tfrac{1}{2}g \cot \tfrac{1}{2}F + p = gN + p, \quad . \quad . \quad (221)$$

and measure this distance back along main rail, then set a hub at *B*, in the center of main track, on a perpendicular to main rail. Set the transit at *B* and bring the line of sight into the vertical plane which contains the center line of main track.

Deflect the angle $F$ and measure $BM = gN + p$, and set a hub at $M$ if desired. On this line measure an additional distance $MS$ equal to the length of the frog tangent selected (never less than the length of frog from point to heel) and set a hub for the $P.C.$ of the curve $SV$. Set up at $S$, backsight to $B$ and run the curve $SV$ in the usual way when its radius is known or assumed.

If the tangent beyond $V$ is fixed by reason of an existing track, or by other conditions, $R$ must first be found in order that the proper degree of curve may be used.

**176½. To Locate the Curve between $S$ and $V$ of Fig. 83,** produce the tangent at $V$ to intersect the center line of main track at $A$. Measure angle $I$, if this is not already known; also measure $AB$. Extend $BS$ to intersect $AV$ at $C$. In triangle $BAC$ one side and all the angles are known, and therefore

$$BC = \frac{AB \sin I}{\sin (I - F)} = gN + p + k + SC.$$

But

$$SC = R \tan \tfrac{1}{2}(I - F) = BC - (gN + p + k).$$

$$\therefore\ R = \frac{BC - (gN + p + k)}{\tan \frac{1}{2}(I - F)}. \qquad \ldots\ldots \qquad (222)$$

If $R$ is fixed by conditions on the ground, or is assumed, equation (222) yields a value of the frog-tangent, $k$, in terms of known quantities, and serves to locate $S$. The $P.T.$ at $V$ may be set from $C$, since $CV = SC = R \tan \frac{1}{2}(I - F)$, or from $A$ by computing $AC$ from the triangle $BAC$.

**177. Three-throw and Tandem Switches** should never be used when they can possibly be avoided, but sometimes limited space or other reasons make their use imperative. A *three-throw switch* is one having two turnouts, either to the same or opposite sides of main track, operated from the same switch-stand. If the switch rails of one turnout clear the switch-rails of the other, but lie between them and their frog, the arrangement has been termed a *tandem switch*. The use of either arrangement is especially objectionable when both turnouts are to the same side of main track. In either case a third frog, called the *middle frog*, or *crotch frog*, must be used. If standard frogs are employed, this will introduce a short piece of tangent at this frog in both turnout curves and will complicate the computations for leads and turnout radii materially. If many such middle frogs are to be used on a given system, these should be manufactured on the proper curves and kept in stock. A careful study of conditions will, however, generally lead to a yard design in which double turnouts and tandem switches are eliminated.

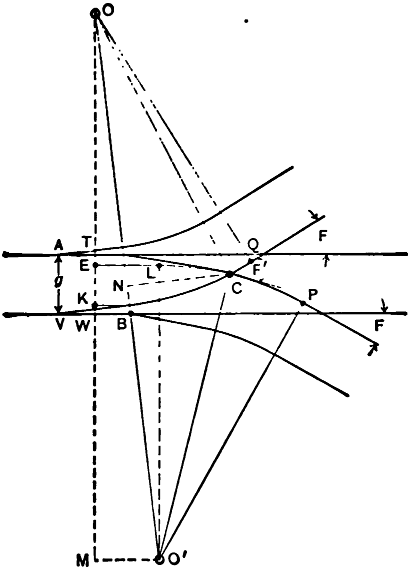


FIG. 84.

**178. Given the Equal Numbers, $N$, the Equal Switch Rails, $s$, of Either a Three-throw or Tandem Switch, the Distance, $d$, between Points of Switches, Measured along Main Rail, to Find the Angle or Number of the Crotch Frog.**

In Fig. 84 let the crotch frog be assumed to be constructed on curved lines. $OC = O'C$ is found by (208); $OM$ and $O'L$ are perpendicular to main rail and $O'M$ and $LE$ are parallel thereto. $ET' = KW = e$ is found by (210). From the figure

$$MO = ME + KO - EK = 2R + g - (g - 2e) = 2(R + e).$$

$$MO' = EL = VB = d.$$

In triangle $OMO'$,

$$\tan MOO' = \frac{d}{2(R+e)},$$

and

$$OO' = 2(R+e) \sec MOO'. \quad . \quad . \quad . \quad . \quad (223)$$

Draw $CN$ perpendicular to $OO'$,

$$\cos \tfrac{1}{2}F' = \frac{\tfrac{1}{2}OO'}{R+\tfrac{1}{2}g}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (224)$$

The above solution for the angle of the crotch frog is for tandem switches, but reduces to that for a three-throw switch when $B$ and $V$ coincide, which reduces $MO'$ to zero and makes $OO' = OM = 2(R+e)$.

The switch-rails are assumed to be straight in above solution.

**179. Given the Frog Number, $N$, the Gauge, $g$, and Distance, $c$, between Center Lines, to Unite a Straight Main Line with a Parallel Siding or Spur, Using Curves of Contrary Flexure Having an Intervening Tangent of Known Length.**

In Fig. 85 first locate the point $C$ by the method of **176.**

From Fig. 85,

$$b = (gN + p + k) \sin F. \quad . \quad . \quad . \quad . \quad . \quad (225)$$

In Fig. 85 produce the curve $LC$ backward to $K$ where its tangent will be parallel to main line. Draw $CT$ perpendicular to $OK$. Angle $KOC = F$, and $KT = R$ vers D.

$$\therefore\ e = b - R \text{ vers } F, \text{ and } d = c - e. \quad . \quad . \quad (226)$$

The problem now reduces to that of Section **132,** angle $y$ being given by (120), $OO'$ by (121), angle $z$ by (122), angle $a$ by (123), and distance $x$ by (124).

Wherever possible the distance $l$ should be at least 30 feet and preferably more. For small distances between centers $l$ may have to be omitted altogether.

EXAMPLE.—Given $N = 10$, $D = 10$, $l = 40$, and $c = 15$ feet. Required $x$ and angle $a$.

By (225), $b = (4.708 \times 10 + 0.42 + 40)0.0999 = 8.73$ feet.

By (226), $e = 8.73 - 573.14 \times 0.00499 = 3.86$ feet, and

$d = 15 - 3.86 = 11.14$ feet.

By (120), $\tan y = \frac{40}{2 \times 573.14} = 0.0349 = \tan 2° 0'$.

By (121), $OO' = \sqrt{(2 \times 573.14)^2 + 40^2} = 1146.97$ feet.

By (122), $\cos z = \left(1 - \dfrac{11.14}{2 \times 573.14}\right) \times 0.99985 = 0.98986 =$
$= \cos 8^\circ\ 10'$.

By (123), $a = 8^\circ\ 10' - 2^\circ\ 0' = 6^\circ\ 10'$.

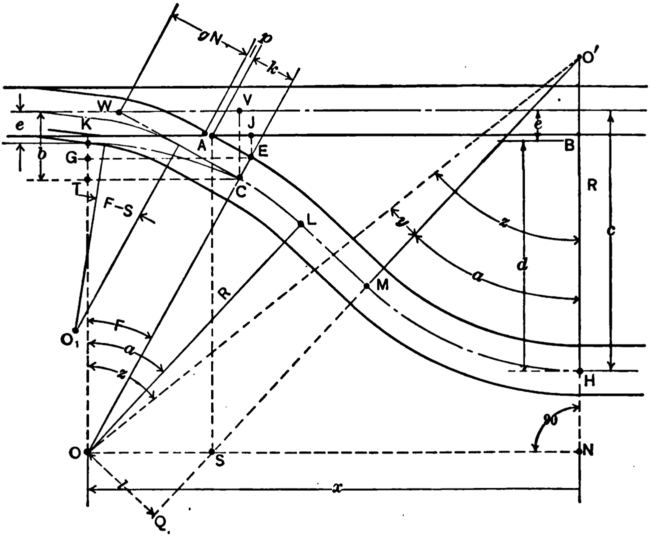


FIG. 85.

From Fig. 85, angle $COL = 6^\circ\ 10' - 5^\circ\ 43'\ 29'' = 0^\circ\ 26'\ 31''$.

By (124), $x = 1146.97 \times 0.14205 = 162.93$ feet.

**180. For the Data Given in 179 to Determine the Quantities Necessary to Unite the Parallel Tracks when the Frog Tangent is Continued to the P.C. of the Side Track Curve.**

In Fig. 86 $R$ or $k$ may be given or assumed, or the point $E$ may be fixed by conditions on the ground. Suppose $R$ known. In triangle $AHL$ we have

$$AH = LH \operatorname{cosec} F, \text{ or } gN + p + k + CH = c \operatorname{cosec} F,$$

whence

$$k = c \operatorname{cosec} F - (gN + p + R \tan \tfrac{1}{2}F). \quad . \quad . \quad . \quad (227)$$

If $k$ is given or assumed, formula (227) yields

$$R=[e \operatorname{cosec} F-(gN+p+k)] \operatorname{cotan} \tfrac{1}{2}F. \quad . \quad . \qquad (228)$$

If $E$ is fixed in position, $AB$ must be determined by measurements in the field, and $AL=c \operatorname{cotan} F$ found from the triangle $AHL$. Then

$$CH=HE=LB=AB-AL=AH-(gN+p+k)=R \tan \tfrac{1}{2}F.$$

$$\therefore\ R=CH \operatorname{cotan} \tfrac{1}{2}F=[c \operatorname{cosec} F-(gN+p+k)] \operatorname{cotan} \tfrac{1}{2}F. \qquad (229)$$

The points $C$ and $E$ and the mid-point of curve, on the radial line through $H$, may be conveniently located by rectangular

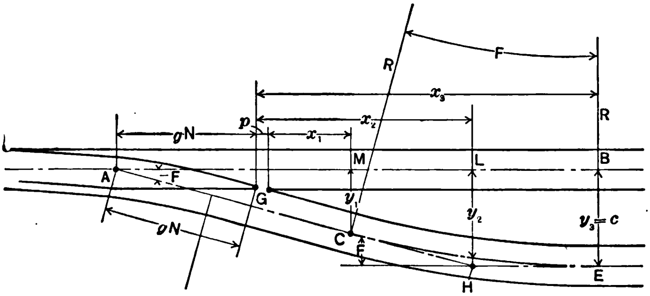


FIG. 86.

coordinates which have a point on the center line of main track opposite $G$ for origin. For the notation shown in the figure we have

$$\left.\begin{array}{ll} x_1=(p+k)\cos F; & y_1=(gN+p+k)\sin F=c-R \operatorname{vers} F \\ x_2=(p+k+CH)\cos F; & y_2=c-R \operatorname{vers} \tfrac{1}{2}F \\ x_3=(p\times k)\cos F+R\sin F; & y_3=c \end{array}\right\} \quad (230)$$

**181. To Lay Out a "Ladder Track."**—At terminals, or stations where large numbers of cars have to be accommodated at one time, the yards may consist of a number of parallel tracks which are connected with the main line and with each other by means of a ladder track, such as is indicated in part by Fig. 87, by extending the frog tangent and locating turnouts to the parallel storage or sorting tracks. The track from which the ladder leads is called the *drill track* and the parallel tracks which the ladder connects with it are called the *body tracks*. A number of arrangements may be made of which the simplest is where there is one frog on the ladder for each body track, as indicated in Fig. 87.

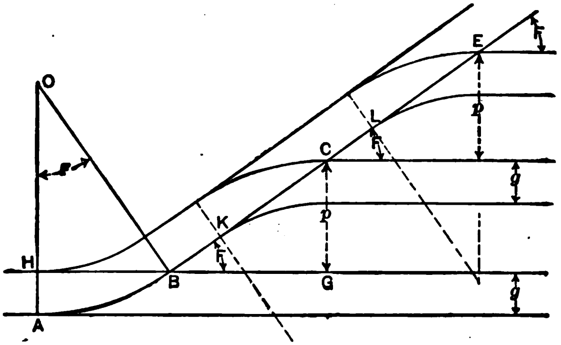


FIG. 87.

The frog-number, $N$, and the distance, $p$, between the body tracks must be known. The distances $BC=CE$ and $BK=CL$ are to be determined. From the figure

$$BC=p \operatorname{cosec} F, \quad \ldots \ldots \ldots \quad (231)$$

$$BK=BC-KC=p \operatorname{cosec} F-L. \quad \ldots \quad (232)$$

If desired, the ladder track may make an angle equal to $2F$ with the drill track, in which case the first of the body tracks is led off of the drill track as an independent turnout, which, in the figure, would be to the right of $B$, while the second body track would lead off from the first turnout from the ladder. That is to say, this first turnout would end in body track No. 3 and would serve as a ladder for No. 2. There would then be only one frog in the ladder for two body tracks. Fig. 88 illustrates the arrangement in outline.

If the ladder track makes an angle equal to $3F$ with the drill track, there will be only one frog in it for three body tracks and the first and second body tracks will lead off of a two-track ladder to the right of $B$ of Fig. 87. The first turnout frog in the ladder proper will lead to body tracks 3 and 4, while the second and subsequent turnout frogs will each lead to three body tracks. Fig. 89 shows the arrangement in outline.

Still other conditions as to the angle which the ladder proper shall make with the drill track may be imposed. It may be that this angle must be greater than *F*, but less than 2*F*, or it may be greater than 2*F*, but less than 3*F*. Again, it may be required that the frogs may be the minimum permissible distance apart, or yet other conditions may be imposed. In each case the frog-angles or numbers and the distances between centers of body tracks must be known, together with any other data which the conditions imposed require. Detailed solutions for such cases, as also for the ladder angle equal to 2*F* and 3*F*, will not be given here. No special difficulty is involved in the determination of the data necessary in order to locate the frog-points.

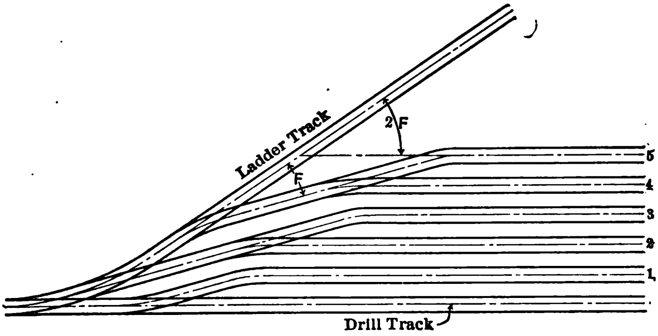


FIG. 88.

### *B. Turnouts from Curves*

**182. The Degree of Turnout to Curved Main Track** may be taken as equal to the sum or difference of the degree of main curve and that of a turnout from straight main track where the same number of frog is used, according as the turnout is to the inside or to the outside of the curved main track. This is not strictly true, but is near enough for all practical purposes.

In Article 15 it will be shown that if the outer rail of the turnout curve is assumed to be tangent to the frog at the theoretical frog-point, and to the main-line rail at the theo-

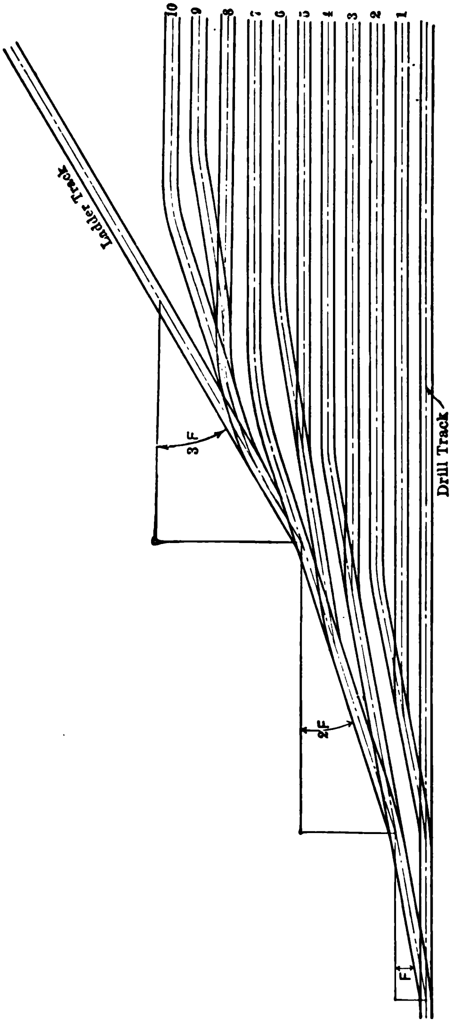


FIG. 89.

retical switch-point (that is, both frog and switch-rail assumed to be curved), the above assumption as to the degree of the turnout is very nearly true, that is:

For turnout to inside of main curve,

$$D_2 = D_1 + D, \quad . \ . \ . \ . \ . \ . \ . \quad (233)$$

For turnout to outside of main curve,

$$D_2 = D_1 - D, \quad . \ . \ . \ . \ . \ . \ . \quad (234)$$

$D$ is the degree of main curve, $D_1$ the degree of turnout from straight main track, and $D_2$ the degree of turnout from the curve.

In Article 15 it is also shown that the leads may be taken the same as for turnouts from straight main track without involving any material error.

**183. For Turnout to Inside of Curved Main Track, Given $R$, the Radius of Main Track, $R_1$, the Radius of a Curve to Connect the Main Track and a Branch Line, the Point of Intersection of Main Line and Branch and the Angle, $I$, between the Branch and the Tangent to Main Curve at the Intersection, Required the Data Needed to Locate the Frog from this Intersection Point.**

Fig. 90 shows the notation which will be used for this case.

Through the theoretical frog-point draw $HO(=R)$ perpendicular to main line side of frog, and $NQ$ perpendicular to its turnout side to meet a line from $O$ at right angles to $NQ$. From $W$, the end of frog tangent, draw $WV$ parallel to $NQ$. $NO = R - \frac{1}{2}g$ and angle $QNO = F$.

$$\therefore \ QN = (R - \tfrac{1}{2}g) \cos F, \text{ and } QO = (R - \tfrac{1}{2}g) \sin F.$$

Also, since $O_1$ is the center of turnout curve having the radius $R_1$, $O_1V = (R - \frac{1}{2}g) \cos F - R_1$, and $OV = (R - \frac{1}{2}g) \sin F - (p+k)$.

In triangle $OVO_1$

$$\tan a = \frac{O_1V}{OV} = \frac{(R - \frac{1}{2}g) \cos F - R_1}{(R - \frac{1}{2}g) \sin F - (p+k)}, \quad . \ . \ . \quad (235)$$

and $\qquad OO_1 = OV \sec a = [(R - \frac{1}{2}g) \sin F - (p+k)] \sec a.$

Draw $OJ$ perpendicular to $O_1E$. Then $O_1J = R_1 - R \cos I$, and

$$\sin b = \frac{O_1J}{OO_1} = \frac{R_1 - R \cos I}{[(R - \frac{1}{2}g) \sin F - (p+k)] \sec a}. \quad . \quad (236)$$

From the figure.

$$x = a+b+(90^\circ - I) - (90^\circ - F) = a+b+F-I, \quad . \quad (237)$$

$$y = 180^\circ - [(90^\circ - a)+(90^\circ - b)] = a+b. \quad . \quad . \quad . \quad (238)$$

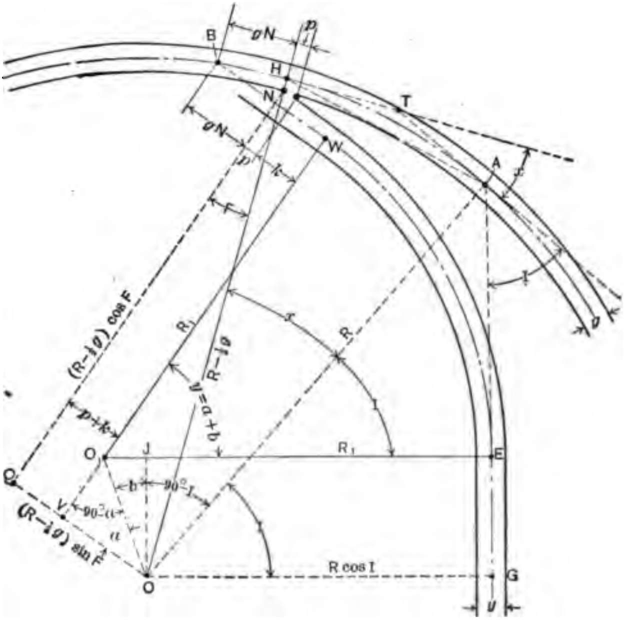


FIG. 90.

From $A$ measure the arc $AH$ = angle $x$ divided by $D$, in chains, and set $H$ opposite the theoretical frog-point. $E$ is located from $A$ by measuring

$$AE = AG - EG = R \sin I - (R_1 - R \cos I) \cot b \quad . \quad (239)$$

The curve $EW$ is now run in the usual way. $W$ is located from $B$, which is at a distance $gN$ back of $H$ on the tangent to the main-line curve at $H$, as indicated in the figure.

Should the main-line curve pass to tangent between $H$ and $A$ of Fig. 90, it may be continued on the ground until it intersects the tangent *GA* at *A*, where the angle *I* is measured, after which the problem becomes the same as above. If preferred the distance may be measured from the *P.T.* of main line curve to the point where *GE* produced meets the main line, after which a perpendicular to *GE* produced is let fall upon a line through the *P.T.* of main-line curve parallel to *GE* produced. The distance from the *P.T.* to *A* is then measured. All the angles of the right-angled triangle, formed as above, and one side now become known, and the other two sides may be computed, after which the problem will be solved as before.

EXAMPLE.—Given a 1° 30′ main-line curve, $I=80°$, $k=40$ feet, and $N=10$. Required angles $x$ and $y$ and the distance *AE* for an 8° connecting curve.

$$\text{By (235), } \tan a=\frac{(3819.83-2.35)\times 0.99502-716.34}{(3819.83-2.35)\times 0.09976-(0.42+40.0)}$$

$$=\frac{3082.13}{340.41}=8.76041=\tan 83° 29'.$$

$$\text{By (236), } \sin b=\frac{716.34-3819.83\times 0.17365}{340.41\times 8.85628}=\frac{53.10}{3014.77}$$

$$=0.01761=\sin 1° 1'.$$

$$\text{By (237),} \qquad x=83° 29'+1° 1'+5° 43\tfrac{1}{2}'-80° 0'=10° 13\tfrac{1}{2}',$$

which calls for 681.7 feet from *H* to *A* on main-line curve.

By (238), $y=a+b=84° 30'$, corresponding to 1056.25 feet around the 8° curve.

By (239), $AE=38.1983\times 0.98481-53.10\times 56.3506=769.2$ ft.

### 184. For the Same Data Given in 183 to Locate the Frog and Run the Connecting Curve when the Turnout is to Outside of Curved Main Line.

Let the notation and the construction lines be as shown in Fig. 91.

In triangle *LOH*, $LO(=R+\frac{1}{2}g)$ is perpendicular to main side of frog, *LH* is perpendicular to turnout side and *OH* is parallel thereto. From the figure,

$$OH=OL \sin OLH=(R+\tfrac{1}{2}g) \sin F, \quad . \ . \ . \quad (a)$$

$$HL=OL \cos OLH=(R+\tfrac{1}{2}g) \cos F, \quad . \ . \ . \quad (b)$$

In triangle $OO_1Q$ ($O_1Q$ parallel to $LH$),

$$OQ = (R+\tfrac{1}{2}g)\sin F + (p+k), \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

$$O_1Q = (R_1+\tfrac{1}{2}g) + (R+\tfrac{1}{2}g)\cos F, \quad . \quad . \quad . \quad . \quad . \quad (d)$$

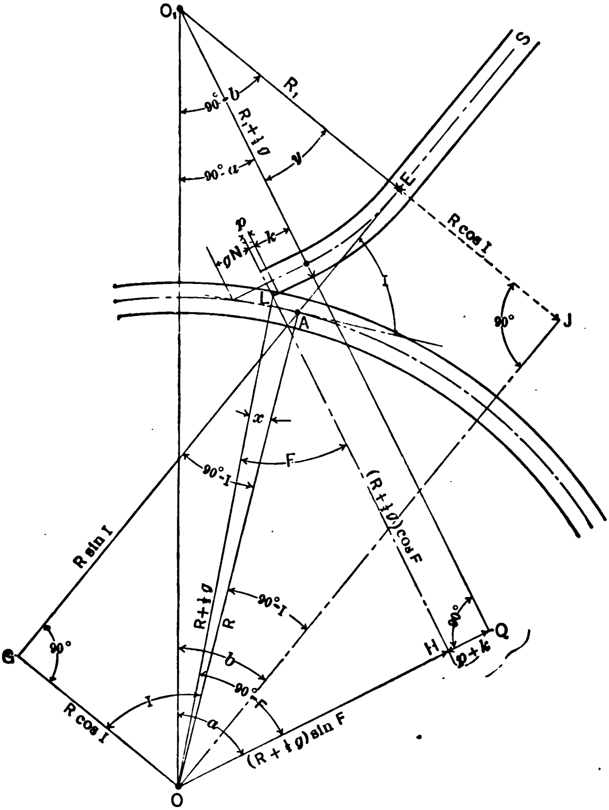


Fig. 91.

$$\tan a = \frac{O_1Q}{OQ} = \frac{(R_1+\frac{1}{2}g)+(R+\frac{1}{2}g)\cos F}{(R+\frac{1}{2}g)\sin F+(p+k)}, \quad . \quad . \quad (240)$$

$$OO_1 = \sqrt{OQ^2+O_1Q^2} = OQ\sec a = O_1Q\operatorname{cosec} a. \quad (241)$$

Produce the tangent $SE$ through $A$, where it intersects the center line of main curve, to $G$, the foot of a perpendicular from $O$. In triangle $AOG$,

$$OG = R\cos I, \quad \text{and} \quad AG = R\sin I,$$

where $I$ is the measured angle between $EA$ and the tangent to main curve at $A$. Draw $OJ$ parallel to $GA$ to meet $O_1E$ produced.

$$O_1J = R_1 + R\cos I,$$

and
$$\sin b = \frac{R_1 + R\cos I}{OO_1}, \quad . \; . \; . \; . \; . \quad (242)$$

also
$$AE = OJ - GA = OO_1\cos b - R\sin I. \quad . \; . \quad (243)$$

From the figure,

$$x = b - (90 - I) - [a - (90 - F)] = b + I - F - a, \quad . \quad (244)$$

$$y = (90 - b) - (90 - a) = a - b. \quad . \; . \; . \; . \; . \; . \; . \quad (245)$$

The field work will now be the same as for **183**.

Example.—Find arc $AL$ and also that from end of frog-tangent to $E$ for turnout curve when the turnout is to outside of a 3° curve, angle $I = 30$ degrees and a No. 10 frog, the joining curve of turnout beyond end of frog tangent to be 8 degrees, and the frog-tangent to be 40 feet long.

$$\text{By (240)},\ \tan a = \frac{(716.34 + 2.35) + (1910.08 + 2.35) \times 0.99502}{(1910.08 + 2.35) \times 0.09976 + (0.42 + 40)}$$

$$= \frac{2621.6}{231.2} = 11.3391 = \tan 84°\ 57\tfrac{1}{2}'.$$

$$\text{By (241)},\quad OO_1 = 231.2 \times 11.3823 = 2631.6.$$

$$\text{By (242)},\ \sin b = \frac{716.34 + 1910.08 \times 0.86603}{2631.6} = 0.90079$$

$$= \sin 64°\ 16'.$$

$$\text{By (243)},\quad AE = 2631.6 \times 0.4342 - 1910.08 \times 0.5 = 187.6 \text{ feet}.$$

By (244), $x = 64^\circ\,16' + 30^\circ\,0' - 5^\circ\,43\tfrac{1}{2}' - 84^\circ\,57\tfrac{1}{2}' = 3^\circ\,35'$.

By (245), $y = 84^\circ\,57\tfrac{1}{2}' - 64^\circ\,16' = 20^\circ\,41\tfrac{1}{2}'$.

Then the arc *AE* will equal 3° 35′ divided by 3° = 1.194 stations = 119.4 feet on main line curve, and the arc which covers $y$ on turnout curve is equal to 20° 41½′ divided by 8° = 2.5865 stations, equal to 258.65 feet.

## ARTICLE 15. TURNOUT FORMULAS FOR CURVED SWITCH-RAILS AND FROGS.

**185.** The treatment of Frogs and Switches given in Article 14 should be followed as a general rule, as agreeing with the practice where switch-rails and frogs are constructed on tangent lines. Both switch-rails and frogs may be built on curved lines, however, and even if straight, the assumption that the turnout curve is tangent to the main rail at the theoretical switch-point, and to the frog at the theoretical frog-point, lead to so much simpler formulas that for many cases they may be used with sufficient precision to meet existing conditions.

### *A. Turnouts from Straight Line.*

**186. Given $N$ and $g$ to find $l$ and $R$, or $D$, for Turnout from Straight Main Track.**

In Fig. 92, *AB* bisects angle $EBC (= F)$.

$$\therefore\ CB = g \cot \tfrac{1}{2}F, \quad \text{or} \quad l = 2gN, \quad . \quad . \quad . \quad . \qquad (246)$$

From triangle *OBC*, $(R + \frac{1}{2}g)^2 - (R - \frac{1}{2}g)^2 = l^2 = (2gN)^2$.

$$\therefore\ R = 2gN^2 = lN, \quad . \quad . \quad . \quad . \quad . \qquad (247)$$

Writing 5730 divided by $D$ for $R$ in (247), we get,

$$D = \frac{5730}{2gN^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (248)$$

For standard gauge track ($g = 4'\,8\tfrac{1}{2}''$) these formulas become,

$l = 9.42N$ feet; $R = 9.42N^2$ feet, and $D = 608 \div N^2$ degrees.

For the distance from theoretical switch-point to theoretical frog-point we have

Frog-distance $(f.d.) = \sqrt{l^2+g^2} = g\sqrt{4N^2+l^2} = g \operatorname{cosec} F.$ (249)

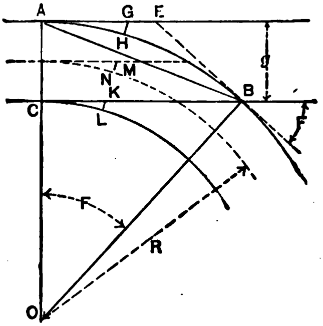


FIG. 92.

### 187. To Find the Theoretical Length of Switch-rail, *s*, for a Given Throw, *t*.

In practice both switch-rails are made the same length, so in Fig. 92 assume $AH = CL =$ distance from $N$ back to head-block on center line of both tracks. Also assume $GH = KL = NM = t$. From the right triangle formed by joining $O$ and $M$, and taking the length of tangent from head-block to $M$ as equal to the arc between head-block and $N$, and calling this length $s$, we have by geometry,

$$(2R+t)\times t = s^2,$$

from which

$$t = \frac{s^2}{2R+t}.$$

Neglecting $t$ in the denominator as small in comparison with $2R$, and solving for $s$, we get

$$s = \sqrt{2Rt} = 2N\sqrt{gt}, \quad . \quad . \quad . \quad . \quad . \quad (250)$$

By writing $R = 5730 \div D$ in (250) and reducing, there results

$$s = 107\sqrt{t \div D}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (251)$$

### 188. Given the Main Frog-number, $N$, to Find the Number, $N_1$, and Lead, $l_1$, of Crotch-frog for a Turnout from Both Sides of Straight Main Track.

In triangle $OCH$, Fig. 93, remembering that $R = 2gN^2$,

$$\cos \tfrac{1}{2}F_1 = \frac{R}{R + \frac{1}{2}g} = \frac{4N^2}{4N^2 + 1}. \qquad (252)$$

Then, by (205),

$$N_1 = \tfrac{1}{2} \cot \tfrac{1}{2}F_1. \; . \; . \; . \qquad (253)$$

From the figure and (206),

$$l_1 = R \tan \tfrac{1}{2}F_1 = \frac{R}{2N_1} = g\frac{N^2}{N_1}; \qquad (254)$$

also,

$$l_1 = \sqrt{(R + \tfrac{1}{2}g)^2 - R^2} = \sqrt{Rg + \tfrac{1}{4}g^2}$$
$$= g\sqrt{2N^2 + \tfrac{1}{4}}. \; . \; . \; . \; . \qquad (255)$$

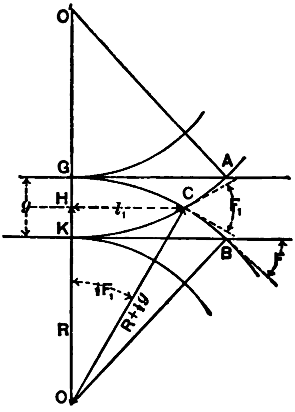


FIG. 93.

Equating these values of $l_1$ and solving for $N_1$ gives

$$N_1 = \frac{N^2}{\sqrt{2N^2 + \frac{1}{4}}}. \; . \; . \; . \; . \; . \qquad (256)$$

If the $\frac{1}{4}$ in denominator be neglected as small compared with $2N^2$, (256) becomes

$$N_1 = \frac{N}{\sqrt{2}} = 0.707N. \; . \; . \; . \; . \; . \qquad (257)$$

If in (255) we neglect the $\frac{1}{4}$ under radical, there results

$$l_1 = gN\sqrt{2} = 1.414gN = 0.707l. \; . \; . \; . \qquad (258)$$

The distance between main and crotch frogs measured along main rail is

$$l - l_1 = 2gN - g\sqrt{2N^2 + \tfrac{1}{4}}, \; . \; . \; . \; . \qquad (259)$$

or, approximately,

$$l - l_1 = 2gN - 1.414gN = 0.586gN = 0.293l. \; . \qquad (260)$$

### 189. To Find the Radius, $R$, of Turnout and Lead, $l_1$, of Crotch-frog in Terms of the Crotch-frog Number, $N_1$.

From (257), $N^2 = 2N_1^2$.

Insert this in (247) and (254), giving

$$R = 2g \,.\, 2N_1^2 = 4gN_1^2, \quad . \quad . \quad . \quad (261)$$

$$l_1 = \frac{2gN_1^2}{N_1} = 2gN_1. \quad . \quad . \quad . \quad . \quad (262)$$

REMARK.—In general the frogs kept in stock by manufacturers do not afford suitable combinations of numbers for double turnouts. For instance, the theoretical number of crotch-frog for a number 8 main frog is, by (256) or (257), $N_1 = 5.66$, and we should be compelled to use a number $5\frac{1}{2}$ or 6 for the crotch-frog; this would necessitate a different rate of curvature from crotch to main frog than from head-block to crotch.

### 190. Given the Numbers of Middle Frog, $N_1$, and of Main Frogs, $N$ and $N'$, to Find the Radii $R_1$ from Point of Switch to Crotch-frog, and $R$ and $R'$, from Crotch to Main Frogs.

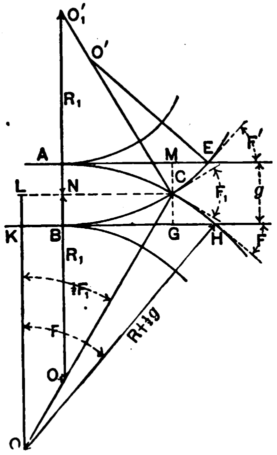


FIG. 94.

In Fig. 94 we have, by (261),

$$O_1N = R_1 = 4gN_1^2,$$

and, by (262),

$$NC = l_1 = 2gN_1.$$

Now if $F_1$, $F$, and $F'$ are the angles of the frogs $N_1$, $N$, and $N'$, the angle

$$COH = F - \tfrac{1}{2}F_1,$$

and

$$CHG = F - \tfrac{1}{2}(F - \tfrac{1}{2}F_1) = \tfrac{1}{2}(F + \tfrac{1}{2}F_1).$$

Since $CG = \frac{1}{2}g$, the triangle $CHG$ yields

$$GH = \tfrac{1}{2}g \cot \tfrac{1}{2}(F + \tfrac{1}{2}F_1). \quad . \quad (263)$$

But, by trigonometry,

$$\cot(\tfrac{1}{2}F + \tfrac{1}{4}F_1) = \frac{1 - \tan\frac{1}{2}F \,.\, \tan\frac{1}{4}F_1}{\tan\frac{1}{2}F + \tan\frac{1}{4}F_1}.$$

Assume $\tan \frac{1}{4}F_1 = \frac{1}{2} \tan \frac{1}{2}F_1$, and write

$$\tan \tfrac{1}{2}F = \frac{1}{2N}, \quad \tfrac{1}{2} \tan \tfrac{1}{2}F_1 = \frac{1}{2} \cdot \frac{1}{2N_1} = \frac{1}{4N_1},$$

and after simplifying and reducing,

$$GH = \frac{2gNN_1}{2N_1 + N} - \frac{g}{4(2N_1 + N)}. \quad . \quad . \quad . \quad (264)$$

The last term is quite small, rarely amounting to as much as one inch, and may be neglected; then

$$GH = \frac{2gNN_1}{2N_1 + N} = \frac{l_1 N}{2N_1 + N} = \frac{lN_1}{2N_1 + N}. \quad . \quad . \quad (265)$$

From the triangles *LCO* and *KHO*,

$$(R + \tfrac{1}{2}g) \cos \tfrac{1}{2}F_1 - (R + \tfrac{1}{2}g) \cos F = \tfrac{1}{2}g,$$

whence

$$R + \tfrac{1}{2}g = \frac{g}{2(\cos \frac{1}{2}F_1 - \cos F)}. \quad . \quad . \quad . \quad . \quad (266)$$

In like manner for the curve *CE*,

$$ME = \tfrac{1}{2}g \cot \tfrac{1}{2}(F' + \tfrac{1}{2}F_1) = \frac{2gN'N_1}{2N_1 + N'}, \quad . \quad . \quad (267)$$

$$R' + \tfrac{1}{2}g = \frac{g}{2(\cos \frac{1}{2}F_1 - \cos F')}. \quad . \quad . \quad . \quad (268)$$

EXAMPLE.—Given $N_1 = 6$, $N = 8$, and $N' = 9$, to find the lead $l_1$, the distances *GH* and *ME*, and radii $R$, $R_1$, and $R'$; $g$ being 4.75 ft.

By (261), $R_1 = 19 \times 6^2 = 684$ ft., an 8° 23′ curve.

By (262), $l_1 = 9.5 \times 6 = 57$ ft.

By (265), $GH = \dfrac{9.5 \times 6 \times 8}{12 + 8} = 22.8$ ft.

By (267), $ME = 24.4$ feet.

By (266) $R = \dfrac{4.75}{2(\cos 4^\circ\ 46' - \cos 7^\circ\ 9')} - 2.38 = 547.4$ ft.,

a 10° 28′ curve.

By (268), $R' = \dfrac{4.75}{2(\cos 4^\circ\ 46' - \cos 6^\circ\ 22)} - 2.38 = 876.4$ ft.

a 6° 32½′ curve.

**191. Given the Number, *N*, of the Two Main Frogs and the Gauge, *g*, to find the Crotch-frog Number, $N_1$, its Lead, $l_1$, and the Radius, $R_1$, of Curve through Crotch when the Double Turnout is to Same Side of Straight Main Track.**

In Fig. 95 the frogs at $B$ and $G$ are of the same number, and may be taken as falling on the same straight line through the center $O$. Angle $O_1GO = 90^\circ - OGL = F$, and the triangle $OO_1G$ is therefore isosceles; hence

$$O_1G = O_1O = OA - O_1O = \tfrac{1}{2}OA,$$

or

$$R_1 + \tfrac{1}{2}g = \tfrac{1}{2}(R + \tfrac{1}{2}g),$$

whence

$$R_1 = \tfrac{1}{2}R - \tfrac{1}{4}g. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (269)$$

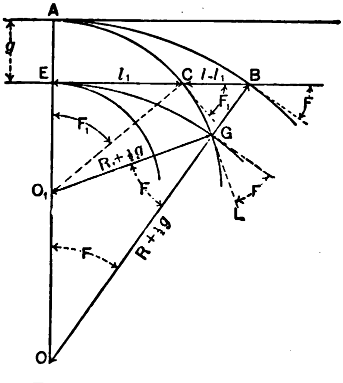


FIG. 95.

Now, by the same reasoning as in **167**, $2gN_1^2 = R_1$, whence

$$N_1 = \sqrt{\frac{R_1}{2g}} = \sqrt{\frac{R}{4g} - \frac{1}{8}}. \quad . \quad . \quad . \quad . \quad (270)$$

Neglecting the $\frac{1}{8}$ under radical and writing $R = 2gN^2$ gives

$$N_1 = \frac{N}{\sqrt{2}} = .707N, \quad . \; . \; . \; . \; . \; . \; . \; . \quad (271)$$

which is identical with (222) for turnouts to opposite sides. For $EC$ and $EB$, as in **167**, $l_1 = 2gN_1$ and $l = 2gN$. Hence

$$CB = l - l_1 = 2g(N - N_1). \quad . \; . \; . \; . \; . \quad (272)$$

Example. — Find $N_1$, $R_1$, and $l - l_1$ where $N = 9$ and $g = 4.75$ ft.

By (247), $R = 9.5 \times 81 = 769.5$ ft., a 7° 27′ curve.
By (269), $R_1 = 384.75 - 1.19 = 383.56$ ft, a 14° 56′ curve.
By (271), $N_1 = .707 \times 9 = 6.36$.
By (272), $CB = l - l_1 = 9.5 \times 2.64 = 25.08$ ft.

Remark.—It may now be seen that the proper combination of frogs for a double turnout to opposite sides applies also where the turnouts are to same side of straight main line. Also they apply to turnouts from *opposite* sides of curved main line when its radius is not less than that required by main frog for straight track.

**192. Given the Number of Main Frogs, $N$, and of Crotch-frog, $N_1$, to Find the Radius of Curve between Frog-points of a Double Turnout to Same Side of Straight Track.**

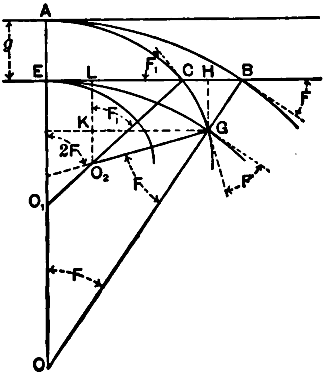


Fig. 96.

In Fig. 96, $O_2G = R_2 + \frac{1}{2}g$, and the chord $CG$ must be determined. The frogs at $B$ and $G$ being of the same number, $O_1GO = GOO_1 = F$ and $CO_1E = F_1$.

**Draw** $GH$ perpendicular to $EB$; then in triangle $BGH$

$$GH = g \cos F.$$

**Draw** $O_2L$ perpendicular and $GK$ parallel to $EB$; from triangles $O_2GK$ and $O_2CL$,

$$(R_2 + \tfrac{1}{2}g)(\cos F_1 - \cos 2F) = KL = GH = g \cos F,$$

whence
$$R_2 + \tfrac{1}{2}g = \frac{g \cos F}{\cos F_1 - \cos 2F}. \quad . \quad . \quad . \quad (273)$$

From triangle $O_2CG$, since $CO_2G = 2F - F_1$,

$$CG = 2(R_2 + \tfrac{1}{2}g) \sin \tfrac{1}{2}(2F - F_1). \quad . \quad . \quad . \quad (274)$$

EXAMPLE.—Given $N = 8$, $N_1 = 6$, and $g = 4.75$, to locate the turnout.

By (247), $R = 608$ ft.; $R_1 = 342$ ft.

By (273), $R_2 + \tfrac{1}{2}g = 274.5$ ft.

By (274), $CG = 22.8$ ft.

### 193. Given the Frog-number, $N$, the Gauge, $g$, and Distance, $p$, between Centers, to Unite Main Line with a Parallel Siding when the Reversing-point is at Frog-point.

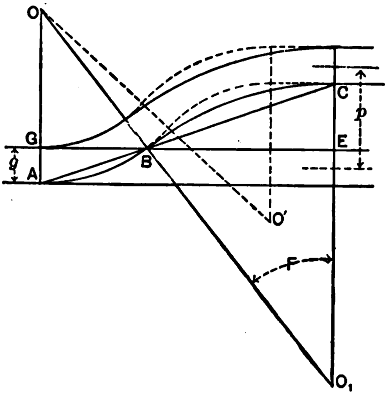


FIG. 97.

In Fig. 97, $BO_1 = R_1 - \tfrac{1}{2}g$ and $BE$ are required.

In triangle $BO_1E$, $BO_1 = R_1 - \tfrac{1}{2}g$, $EO_1 = R_1 + \tfrac{1}{2}g - p$, and angle $BO_1E = F$. By trigonometry,

$$\frac{(R_1 - \frac{1}{2}g) + (R_1 + \frac{1}{2}g - p)}{(R_1 - \frac{1}{2}g) - (R_1 + \frac{1}{2}g - p)} = \frac{\tan \frac{1}{2}(180° - F)}{\tan \frac{1}{2}F}$$

or
$$\frac{2R_1 - p}{p - g} = \frac{\cot \frac{1}{2}F}{\tan \frac{1}{2}F} = 4N^2,$$

whence
$$R_1 = 2(p - g)N^2 + \tfrac{1}{2}p, \quad . \quad . \quad . \quad . \quad . \quad (275)$$

$$BE = (R_1 - \tfrac{1}{2}g) \sin F. \quad . \quad . \quad . \quad . \quad . \quad . \quad (276)$$

From the similar triangles $ABG$ and $BCE$, $\frac{BE}{p-g} = \frac{l}{g}$, from which

$$BE = \frac{(p - g)l}{g} = \left(\frac{p}{g} - 1\right)l. \quad . \quad . \quad . \quad . \quad (277)$$

**Example.**—Find $R_1$ and $BE$ when $N = 8$, $p = 12.35$ ft., $g = 4.75$ ft.

By (275), $R_1 = 15.2 \times 64 + 6.2 = 979$ ft., a 5° 51′ curve.
By (248), $l = 9.5 \times 8 = 76$ ft.
By (277), $BE = (2.6 - 1) \times 76 = 121.6$ ft.

**Remark.**—If space requires that the turnout get away from main line more rapidly than by the above method, we can assume the second radius equal to or less than the radius of turnout and find the reversing-point by **131**, and then compute $BE$.

### *B. Turnouts from Curves.*

**194. Given the Radius of Main Curve, the Frog-number, and the Gauge, to Find the Radius and Lead of Turnout from Concave Side of Main Line.**

In Fig. 98, $AB$ is the outer rail of turnout, $CB$ the inner rail of main track. In triangle $OAB$, since $O_2BA = OAB$,

$$OBA - OAB = F,$$

$$OBA + OAB = 180° - \theta,$$

and $OA = R + \frac{1}{2}g$, $OB = R - \frac{1}{2}g$.

Then, by trigonometry,

$$\frac{(R+\frac{1}{2}g)+(R-\frac{1}{2}g)}{(R+\frac{1}{2}g)-(R-\frac{1}{2}g)}=\frac{\tan\frac{1}{2}(180-\theta)}{\tan\frac{1}{2}F}=\frac{\cot\frac{1}{2}\theta}{\tan\frac{1}{2}F}.$$

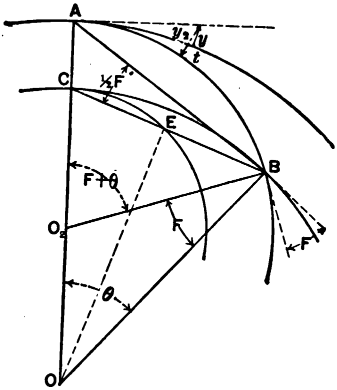


FIG. 98.

Reducing, $$\cot\tfrac{1}{2}\theta=\frac{2R}{g}\tan\tfrac{1}{2}F=\frac{R}{gN}. \quad \ldots\ldots \quad (278)$$

Then $$l=BC=2(R-\tfrac{1}{2}g)\sin\tfrac{1}{2}\theta. \quad \ldots \quad (279)$$

If the length of $AB$ is wanted, we can show that the angle $ABC=\frac{1}{2}F$; and by solving the triangle $ABC$, since $ACB=90°+\frac{1}{2}\theta$,

$$AB=\frac{g\cos\frac{1}{2}\theta}{\sin\frac{1}{2}F}. \quad \ldots\ldots \quad (280)$$

To find $R_2$, from triangle $O_2AB$,

$$2(R_2+\tfrac{1}{2}g)\sin\tfrac{1}{2}(F+\theta)=AB. \quad \ldots\ldots \quad (281)$$

Or, in triangle $BO_2C$,

$$\frac{(R_2+\frac{1}{2}g)+(R_2-\frac{1}{2}g)}{(R_2+\frac{1}{2}g)-(R_2-\frac{1}{2}g)}=\frac{\tan\frac{1}{2}[180-(F+\theta)]}{\tan\frac{1}{2}F}=\frac{\cot\frac{1}{2}(F+\theta)}{\tan\frac{1}{2}F}.$$

Reducing and solving for $R_2$,

$$R_2 = \frac{g}{2} \cdot \frac{\cot \frac{1}{2}(F + \theta)}{\tan \frac{1}{2}F} = \frac{g}{2} \cdot \cot \frac{1}{2}F \cdot \cot \frac{1}{2}(F + \theta). \quad . \qquad (282)$$

But, from trigonometry

$$\cot \frac{1}{2}(F + \theta) = \cot (\frac{1}{2}F + \frac{1}{2}\theta) = \frac{1 - \tan \frac{1}{2}F \cdot \tan \frac{1}{2}\theta}{\tan \frac{1}{2}F + \tan \frac{1}{2}\theta}.$$

Substitute this in (282) and write

$$\cot \frac{1}{2}F = 2N, \quad \tan \frac{1}{2}F = \frac{1}{2N}, \quad \tan \frac{1}{2}\theta = \frac{gN}{R},$$

and reduce; then

$$R_2 = \frac{2gN^2(R - \frac{1}{2}g)}{R + 2gN^2}. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (283)$$

For $2gN^2$ write $R_1$, the radius of turnout from straight track; and neglect the $\frac{1}{2}g$ in numerator as small compared with $R$; then

$$R_2 = \frac{RR_1}{R + R_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (284)$$

Now write

$$R = \frac{5730}{D}, \quad R_1 = \frac{5730}{D_1}, \quad R_2 = \frac{5730}{D_2}$$

and reduce, yielding

$$D_2 = D + D_1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (285)$$

Formula (285) affords an easy method of finding the degree of turnout curve, or, if preferred, the radius may be first found by (284).

Draw $OE$ to the mid-point of $CB$; $OE$ does not differ greatly from $OB$ or $OC$; so, if we write $OE = R - \frac{1}{2}g$, there results

$$l = 2(R - \frac{1}{2}g) \tan \frac{1}{2}\theta = 2(R - \frac{1}{2}g)\frac{gN}{R} = 2gN - \frac{g^2N}{R}. \qquad (286)$$

The last term is quite small, even in the most extreme case likely to arise in practice; for a turnout from a 6° curve with number 8 frog it amounts to only $2\frac{1}{4}$ inches; neglecting it, we may write, as for straight main track,

$$l = 2gN. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (287)$$

EXAMPLE.—Turnout from inside of a 4° curve, $N = 8$, $g = 4.75$ ft.

By (247), $R_1 = 9.5 \times 64 = 608$ ft., a 9° 26′ curve.

By (285), $D_2 = 4° + 9° \ 26' = 13° \ 26'$, for which $R_2 = 426.8$.

By (287), $l = 76$ ft.

### 195. Given the Frog-number, the Gauge and Radius of Main Curve, to Find the Lead and Radius (or Degree) of Turnout from Convex Side of Main Line.

In triangle $AOB$ of Fig. 99, $A + B = 180° - \theta$,

$$A - B = (180° - O_2AB) - (180° - O_2BA - F) = F.$$

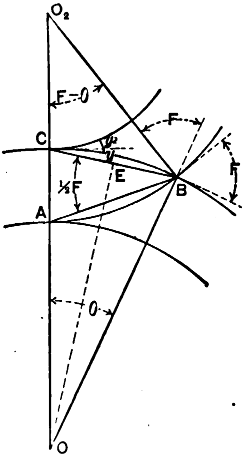


FIG. 99.

By trigonometry,

$$\frac{(R + \frac{1}{2}g) + (R - \frac{1}{2}g)}{(R + \frac{1}{2}g) - (R - \frac{1}{2}g)} = \frac{\tan \frac{1}{2}(180 - \theta)}{\tan \frac{1}{2}F},$$

or

$$\frac{2R}{g} = \frac{\cot \frac{1}{2}\theta}{\tan \frac{1}{2}F}$$

whence

$$\cot \tfrac{1}{2}\theta = \frac{2R}{g} \tan \tfrac{1}{2}F = \frac{R}{gN}. \quad . \quad . \quad . \quad . \quad (288)$$

From triangle $OCB$,

$$l = CB = 2(R + \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta. \quad . \quad . \quad . \quad . \qquad (289)$$

Assuming $OE = R + \frac{1}{2}g$,

$$l = 2(R + \tfrac{1}{2}g) \tan \tfrac{1}{2}\theta$$

$$2(R + \tfrac{1}{2}g) \cdot \frac{gN}{R} = 2gN + \frac{g^2N}{R}. \quad . \quad . \quad . \quad . \qquad (290)$$

Neglecting the last term, as in **194**,

$$l = 2gN, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (291)$$

which is the same as (246).

In triangle $CO_2B$, $O_2 = F - \theta$.

$$\therefore \tan \tfrac{1}{2}O_2 = \tan (\tfrac{1}{2}F - \tfrac{1}{2}\theta).$$

We may now follow the same line of reasoning by which (284) was derived, or more simply by assuming the tangent of the difference of two small angles equal to the difference of their tangents; that is, $\tan \frac{1}{2}O_2 = \tan \frac{1}{2}F - \tan \frac{1}{2}\theta$.

Now it can be easily shown that $\tan \frac{1}{2}O_2 = \frac{gN}{R_2}$; therefore

$$\frac{gN}{R_2} = \frac{1}{2N} - \frac{gN}{R},$$

whence
$$\frac{1}{R_2} = \frac{1}{2gN^2} - \frac{1}{R} = \frac{1}{R_1} - \frac{1}{R},$$

from which
$$R_2 = \frac{RR_1}{R - R_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (292)$$

Write $R_2 = \frac{5730}{D_2}$, $R_1 = \frac{5730}{D_1}$, $R = \frac{5730}{D}$, and solve for $D_2$.

$$D_2 = D_1 - D, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (293)$$

in which $D_1$ is the degree of turnout from straight track.

Example.—Turnout from outside of a 4° curve, $N = 8$, $g = 4.75$.

By (247), $R_1 = 9.5 \times 64 = 608$ ft., a 9° 26′ curve.

By (293), $D_2 = 9° 26' - 4° = 5° 26'$, for which $R = 1054.9$.

By (291), $l = 9.5 \times 8 = 76$ ft.

From (288) we have, by inverting,

$$\tan \tfrac{1}{2}\theta = \frac{38}{1432.7} = \tan 1° 31'$$

and, by (289),

$$l = 2870 \times \sin 1^\circ 31' = 75.97 \text{ ft.},$$

a difference of only 0.03 ft. from the value given by (291).

**196. Given the Distance $p$ between Center Lines of Curved Main Line and Side Track, the Frog-angle, $F$ (or Number, $N$), and Gauge, $g$, to Find the Radius and Central Angle of Curve beyond Frog-point.**

FIRST CASE.—*Turnout from outside of main line.*

In Fig. 100, $O$ is the center of main curve, $O_1$ the center of curve whose radius is required. In triangle $BOC$,

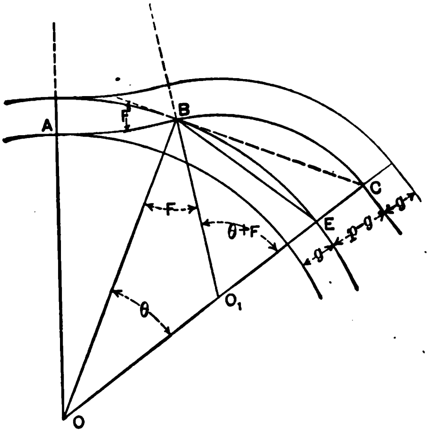


FIG. 100.

$$CO = R + p - \tfrac{1}{2}g, \quad BO = R + \tfrac{1}{2}g.$$

By the same reasoning as in **194**,

$$\cot \tfrac{1}{2}\theta = \frac{2R+p}{p-g}\tan \tfrac{1}{2}F = \frac{2R+p}{2N(p-g)}. \quad . \quad . \quad (294)$$

In triangle $OO_1B$, $O_1B = R_1 - \frac{1}{2}g$; then, by the law of sines,

$$R_1 - \tfrac{1}{2}g = \frac{\sin\theta}{\sin(F+\theta)}(R + \tfrac{1}{2}g). \quad . \quad . \quad . \quad . \quad . \quad (295)$$

Also, $$BE = 2(R + \tfrac{1}{2}g)\sin \tfrac{1}{2}\theta. \quad . \quad . \quad . \quad . \quad . \quad . \quad (296)$$

SECOND CASE.—*Turnout from inside of main track.*

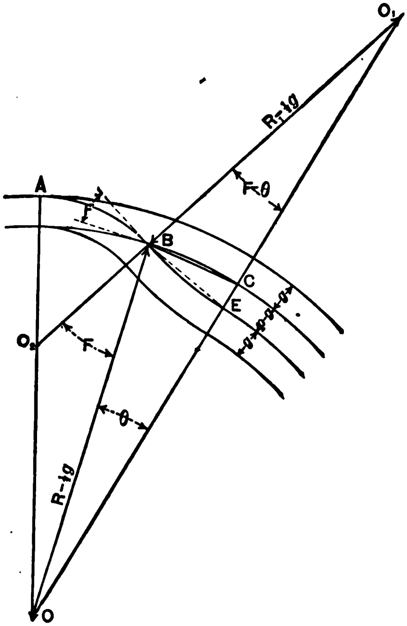


FIG. 101.

In Fig. 101, we have from triangle *BOE*, reasoning as in **195**,

$$\cot \tfrac{1}{2}\theta = \frac{2R - p}{p - g} \tan \tfrac{1}{2}F = \frac{2R - p}{2N(p - g)}; \quad . \quad . \quad . \quad (297)$$

and from triangle $OBO_1$,

$$R_1 - \tfrac{1}{2}g = \frac{\sin \theta}{\sin(F - \theta)}(R - \tfrac{1}{2}g). \quad . \quad . \quad . \quad . \quad . \quad . \quad (298)$$

Also, $$BC = 2(R - \tfrac{1}{2}g) \sin \tfrac{1}{2}\theta, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (299)$$

and $$BE = 2(R_1 - \tfrac{1}{2}g) \sin \tfrac{1}{2}(F - \theta). \quad . \quad . \quad . \quad . \quad . \quad (300)$$

When $\theta$ is greater than $F$, sin $(F - \theta)$ is negative, and center $O_1$ falls on same side as $O$, and

$$R_1 + \tfrac{1}{2}g = \frac{\sin\theta}{\sin(\theta - F)}(R - \tfrac{1}{2}g), \quad . \quad . \quad . \quad . \quad . \quad . \quad (301)$$

$$BE = 2(R_1 + \tfrac{1}{2}g)\sin\tfrac{1}{2}(\theta - F). \quad . \quad . \quad . \quad . \quad . \quad (302)$$

### *C. The Stub Lead.*

**197.** When the frog-number exceeds seven, the length of switch-rail required to give the necessary clearance at heel becomes greater than is allowed in practice. To overcome this difficulty slightly more curvature is given the switch-rail; moreover the physical point of switch is necessarily some distance in advance of the theoretical point. The distance from heel of switch to point of main frog will then be the same as from head-block of stub switch to main frog point, and is termed the **Stub Lead.** If to this distance the length of switch-rail be added, we get the distance from the head-block of a point switch to the point of main frog, which is the **Short Lead** required in practice

**198. Given the Throw, $t$, the Gauge, $g$, and the Frog-number, $N$, to Find the Stub Lead, $s.l.$**

In Fig. 102, $KB$ is the stub lead required; $GN = KL$, the throw.

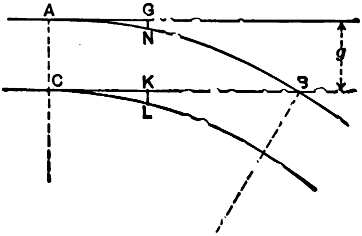


FIG. 102.

From (246), $l = CB = 2gN,$

and from (250), $s = CK = 2N\sqrt{gt}.$

From the figure,

$$KB = CB - CK,$$

or $$s.l. = 2N(g - \sqrt{gt}). \quad . \quad . \quad . \quad . \quad . \quad . \quad (303)$$

Formula (303) may be employed for turnouts from curves as well as straight lines, since it was shown that the formulas from which it was derived may be employed even when the curvature of main track is considerable.

Below is a table of values of $(g - \sqrt{gt})$ for some of the more common values of $g$ and $t$.

TABLE OF VALUES OF $g - \sqrt{gt}$.

| 3 Feet Gauge. | | 4 Feet 8½ Inch Gauge. | | 4 Feet 9 Inch Gauge. | |
|---|---|---|---|---|---|
| Throw. | $g - \sqrt{gt}$. | Throw. | $g - \sqrt{gt}$. | Throw. | $g - \sqrt{gt}$. |
| Inches. | Feet. | Inches. | Feet. | Inches. | Feet. |
| 3 | 2.13 | 5 | 3.306 | 5 | 3.343 |
| 3½ | 2.06 | 5½ | 3.239 | 5½ | 3.275 |
| 4 | 2.00 | 5¾ | 3.206 | 5¾ | 3.242 |

EXAMPLE.—Find the stub lead for $N = 8$, $g = 4.75$ ft., $t = 5$ inches.

From the table,

$$g - \sqrt{gt} = 3.343 \text{ ft.},$$

and, by (303),

$$s.l. = 16 \times 3.343 = 53.49 \text{ ft.}$$

**199. Curving Rails.**—The proper curvature for a rail when bent to fit a given curve is determined by the mid-ordinate measured from a cord stretched between the end-points of inside faces of rail-head. To determine this ordinate, substitute the half length of rail, in decimals of one hundred feet, for $n$ in formula (18). Thus, for a 30-ft. rail,

$$M = \tfrac{7}{8}(0.15)^2 D = 0.0197D \text{ ft.} = 0.236D \text{ ins.} \quad . \quad . \quad (a)$$

For a 33-ft. rail,

$$M = \tfrac{7}{8}(0.165)^2 D = 0.024D \text{ ft.} = 0.288D \text{ ins.} \quad . \quad . \quad (b)$$

But by (248) $D = \dfrac{5730}{2 \times 4.708 N^2}$ for standard-gauge track, and this substituted in (a) gives

$$M, \text{ in inches}, = \frac{144}{N^2}, \text{ (nearly)}. \quad . \quad . \quad . \quad (304)$$

By inserting above value of $D$ in ($b$) there results

$$M\text{, in inches, } = \frac{175}{N^2}\text{, (nearly).} \quad . \; . \; . \quad (305)$$

When the turnout is from a curve compute $M$ from (304), and the mid-ordinate for a rail 30 feet long on main curve by (303); then the mid-ordinate for turnout rail will be the sum or difference of these values according as the turnout is from concave or convex side of main curve.

**200. The Turnout Table** below gives the frog-angle, the radius of turnout from a straight track and its degree, the theoretical lead, the theoretical length of switch-rail for $t = 5$ inches, and the stub lead for $t = 5$, 5½, and 5¾ inches for standard gauge track, and frog-numbers from 4 to 15 inclusive.

Suppose the shortened lead to be wanted for a number 8 frog when $t = 5\frac{3}{4}$ inches, and the switch-points are 16.5 feet long. From the table, the stub lead is 51.3 feet, which, added to 16.5, gives 67.8 feet as against 67.65 feet given in the table of practical leads recommended by the American Railway Engineering Association for the distance from actual switch-

## TURNOUT TABLE FOR STRAIGHT TRACK.

4 FEET 8½ INCH GAUGE.

| Frog No. | Frog Angle. | | Theoretical Lead. | Turnout Radius. | Degree of Turnout. | | Theoretical Switch-rail for $t = 5$ In. | Stub-lead for a Throw of | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 5 In. | 5½ In. | 5¾ In. |
| | ° | ′ | feet | feet | ° | ′ | feet | feet | feet | feet |
| 4 | 14 | 15 | 37.67 | 150.7 | 38 | 2 | 11.20 | 26.46 | 25.91 | 25.65 |
| 5 | 11 | 25 | 47.08 | 235.4 | 24 | 21 | 14.01 | 33.08 | 32.39 | 32.06 |
| 5½ | 10 | 23 | 51.79 | 284.9 | 20 | 7 | 15.41 | 36.39 | 35.63 | 35.27 |
| 6 | 9 | 32 | 56.50 | 339.0 | 16 | 54 | 16.81 | 39.70 | 38.87 | 38.47 |
| 6½ | 8 | 48 | 61.21 | 397.9 | 14 | 24 | 18.21 | 43.00 | 42.11 | 41.68 |
| 7 | 8 | 10 | 65.92 | 461.4 | 12 | 25 | 19.61 | 46.31 | 45.35 | 44.88 |
| 7½ | 7 | 38 | 70.63 | 529.7 | 10 | 49 | 21.01 | 49.62 | 48.59 | 48.09 |
| 8 | 7 | 9 | 75.33 | 602.7 | 9 | 30½ | 22.41 | 52.93 | 51.82 | 51.30 |
| 8½ | 6 | 44 | 80.04 | 680.4 | 8 | 25 | 23.81 | 56.24 | 55.06 | 54.50 |
| 9 | 6 | 22 | 84.75 | 762.7 | 7 | 31 | 25.21 | 59.54 | 58.30 | 57.71 |
| 9½ | 6 | 2 | 89.46 | 849.8 | 6 | 45 | 26.61 | 62.85 | 61.54 | 60.90 |
| 10 | 5 | 44 | 94.17 | 941.7 | 6 | 5 | 28.01 | 66.16 | 64.78 | 64.12 |
| 11 | 5 | 12 | 103.58 | 1139.4 | 5 | 2 | 30.81 | 72.78 | 71.26 | 70.53 |
| 12 | 4 | 46 | 113.00 | 1356.0 | 4 | 13½ | 33.61 | 79.39 | 77.74 | 76.94 |
| 13 | 4 | 24 | 122.42 | 1591.4 | 3 | 36 | 36.42 | 86.01 | 84.21 | 83.36 |
| 14 | 4 | 5 | 131.83 | 1845.7 | 3 | 6 | 39.22 | 92.62 | 90.69 | 89.77 |
| 15 | 3 | 49 | 141.25 | 2118.7 | 2 | 42 | 42.02 | 99.24 | 97.17 | 96.18 |

rail point to theoretical frog-point, when both switch-point and frog are straight.

For a number 10 frog the table here gives 80.62 feet for the lead, as against 77.51 from the table of practical leads above referred to, while for a number 12 frog with 22 feet points in both cases the two values are 98.94 and 100.30 feet, respectively.

## ARTICLE 16. CROSSOVERS. INTERSECTING TRACKS. WYES.

### 201. Given the Equal Frog Numbers, *N*, the Distance between Centers, *c*, and the Gauge, *g*, to Locate a Crossover between Parallel Straight Tracks.

In Fig. 103 let *A* be the location of actual frog-point on one track, and *B* the desired location of actual frog-point on the other track.

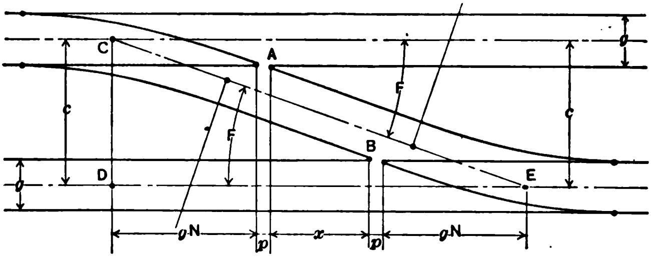


FIG. 103.

Extend the center line of crossover to intersect center lines of parallel tracks at *C* and *E*. From triangle *ECD*, *ED*=*c* cot ***F***, and, as is evident from the figure,

$$x = c \cot F - 2gN - 2p. \quad . \quad . \quad . \quad (306)$$

But, from trigonometry,

$$\cot F = \frac{\cot^2 \frac{1}{2}F - 1}{2 \cot \frac{1}{2}F} = \frac{4N^2 - 1}{4N} = N - \frac{1}{4}N.$$

$$\therefore \quad x = cN - \frac{c}{4N} - 2gN - 2p = N(c - 2g) - \frac{c}{4N} - 2p. \quad . \quad (307)$$

The distance along parallel tracks between theoretical frog-points is $x + 2p$.

TABLE OF DISTANCES BETWEEN ACTUAL FROG-POINTS BY FORMULA (307) FOR CROSSOVERS BETWEEN PARALLEL STRAIGHT TRACKS.

| *N.* | *F.* | *p* in Ft. | Distance *c* between Track Centers. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 12.5 | 13.0 | 13.5 | 14.0 | 14.5 | 15.0 | 15.5 | 16.0 |
| 7 | 8° 10′ 16″ | 0.29 | 20.58 | 24.06 | 27.54 | 31.01 | 34.51 | 37.99 | 41.48 | 44.98 |
| 8 | 7 9 10 | 0.33 | 23.61 | 27.59 | 31.58 | 35.56 | 39.55 | 43.53 | 47.51 | 51.50 |
| 8 | 6 21 35 | 0.37 | 26.66 | 31.15 | 35.63 | 40.12 | 44.61 | 49.09 | 53.58 | 58.06 |
| 9½ | 6 1 32 | 0.40 | 28.16 | 32.90 | 37.64 | 42.37 | 47.11 | 51.85 | 56.58 | 61.32 |
| 10 | 5 43 29 | 0.42 | 29.68 | 34.67 | 39.63 | 44.64 | 49.63 | 54.62 | 59.60 | 64.59 |
| 11 | 5 12 18 | 0.46 | 32.72 | 38.21 | 43.70 | 49.19 | 54.67 | 60.16 | 65.65 | 71.14 |
| 12 | 4 46 19 | 0.50 | 35.74 | 41.73 | 47.72 | 53.71 | 59.70 | 65.69 | 71.68 | 77.67 |
| 15 | 3 49 6 | 0.62 | 44.80 | 52.39 | 59.78 | 67.28 | 74.77 | 82.26 | 89.75 | 97.24 |
| 16 | 3 34 47 | 0.67 | 47.80 | 55.79 | 63.79 | 71.78 | 79.77 | 87.76 | 95.75 | 103.75 |
| 18 | 3 10 56 | 0.75 | 53.83 | 62.82 | 71.82 | 80.81 | 89.80 | 98.80 | 107.79 | 116.78 |

**202. Given the Unequal Frog Numbers, *N*, and *N′*, the Distance, *c*, between Centers, and the Gauge, *g*, to Locate a Crossover between Parallel Straight Tracks.**

Let the notation be as shown in Fig. 104. Some latitude in the selection of $R$ may be allowed, but it is probably best to take it about equal to the radius of turnout which has the larger-angled frog, and to make the curve tangent to the heel of the smaller-angled frog. This will require the insertion of a short piece of tangent between the heel of the larger-angled frog and the beginning of the curve.

From triangle $CHL$, since the side $CH(=R\tan\frac{1}{2}(F-F')+k'+p'+gN')$ is known,

$$q'=LH=CH\cos F', \quad \text{and} \quad n=CL=CH\sin F', \quad . \quad (a)$$

In triangle $ECG$, $m=c-n$, and therefore

$$EC=gN+p+k+R\tan\tfrac{1}{2}(F-F')=m\operatorname{cosec}F \quad . \quad . \quad (b)$$

and

$$q=EG=m\cot F. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

From $(b)$,

$$k=m\operatorname{cosec}F-[gN+p+R\tan\tfrac{1}{2}(F-F')]. \quad . \quad (308)$$

The distance between actual frog-points, measured along the parallel tracks, is, from the figure,

$$x=(q+q')-(gN+p+gN'+p'). \quad . \quad . \quad . \quad (309)$$

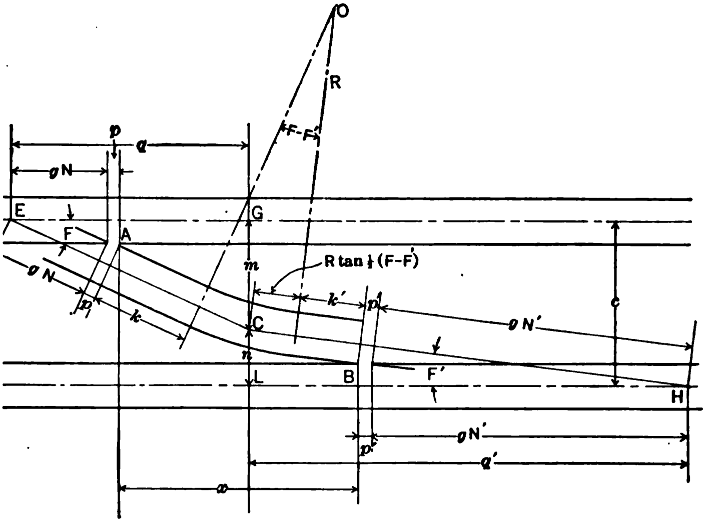


FIG. 104.

**203. Crossovers between Concentric Curved Tracks** sometimes are a necessity, but they should be avoided whenever possible. If they must be inserted, the same frog-numbers should be used on both tracks. The distance between frog-points, measured around a curve midway between the center lines of the two tracks may be taken, with sufficient precision for practical purposes, the same as for a crossover between parallel straight tracks. The heels of the two frogs are then to be joined by a curved track, tangent at the heels, and having its mid-point midway between the center lines of the curved tracks and midway between the frog-points. The radius of this curve need not ordinarily be found, as the heels of the frogs and the mid-point above mentioned should suffice for its location on the ground.

**204. To Connect two Intersecting Straight Tracks which Make a Comparatively Small Angle with Each Other, by Means of a Reversed Curve; Given the Frog Numbers $N$ and $N'$, the Angle $I$ and the Distance from the $P. I.$ to the Actual Point of One of the Frogs and also the Two Radii of the Reversed Curve which is Tangent to the Heels of both Frogs.**

In Fig. 105 the distance $x$, measured along one of the intersecting tracks, and the angles $a$ and $b$ must be found and also

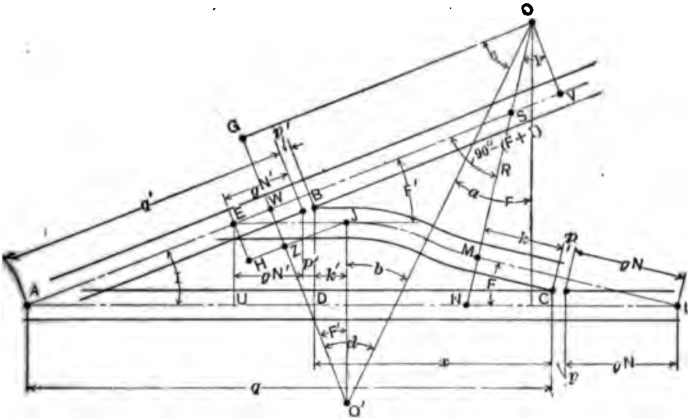


FIG. 105.

the distance from the $P.I.$ to the other frog-point. Let $AC=q$ be known.

In the right triangle $LMN$, $LM$, and angle $F$ are known.

$$\therefore\ LN=(gN+p+k)\sec F, \quad \text{and} \quad MN=(gN+p+k)\tan F.$$

In triangle $ASN$, $NA=q-NC=q-[LN-(gN+p)]$ is known and all the angles. Solve for $AS$ and $NS$.

In the right triangle $OVS$, $OS=R-(NS-MN)$ and all the angles are known. Therefore, $OV=OS\cos I$, and $SV=OS\sin I$.

In the right triangle $EHJ$, $EJ=gN'+p'+k'$, and angle $EJH=F'$ are known. Therefore, $JH=EJ\cos F'$ and $EH=WZ=EJ\sin F'$.

In the right triangle $O'JZ$, $JO'=R'$ and angle $F'$ are known. Therefore, $O'Z=R'\cos F'$, and $ZJ=R'\sin F'$. $EW=HJ-ZJ$.

In the right triangle $O'GO$, $OO'=R+R'$ and $O'G=O'Z+ZW+WG(=VO)$ are known. Therefore, $\sin c=O'G\div O'O$, and angle $d=90°-c$ become known.

$$\therefore\ b=d-F', \quad \text{and} \quad a=90°-(c+I). \quad . \quad . \quad (310)$$

Also $$q'=AS+SV-OG-EW+gN'. \quad . \quad . \quad . \quad (311)$$

In the right triangle $AEU$, $AE = q' - gN'$, and $AU = AE \cos I$.

$$\therefore\ x = q - AE \cos I - p' - gN'. \quad . \quad . \quad . \qquad (312)$$

**205. To Connect two Intersecting Straight Tracks by a Simple Curve when the Intersection Angle, *I*, is Large. Given the Frog Numbers, the Angle *I* and Radius, *R*, to Find Distances from the *P. I.* to the Actual Points of Frogs.**

FIRST CASE. *Frog-numbers Equal.*

In triangle $AGD$ of Fig. 106, $GD = gN + p + k + R \tan \frac{1}{2}(I - 2F)$ $GAD = 90° - \frac{1}{2}I$ and $ADG = 180° - [(90° - \frac{1}{2}I) + F] = 90° + \frac{1}{2}I - F$.

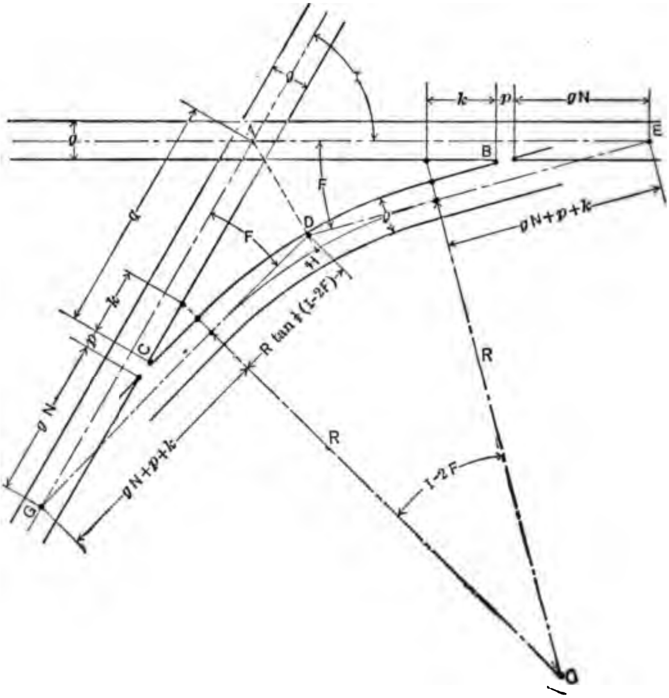


FIG. 106.

From triangle $AGD$

$$AG = GD \frac{\sin ADG}{\sin GAD}.$$

Evidently $q = AC = GA - GC$.

By substituting values

$$q=[gN+p+k+R\ \tan\ \tfrac{1}{2}(I-2F)]\frac{(\sin\ 90+\frac{1}{2}I-F)}{\sin\ (90-\frac{1}{2}I)}-(gN+p);$$

or

$$q=[gN+p+k+R\ \tan\ (\tfrac{1}{2}I-F)]\frac{\cos(\frac{1}{2}I-F)}{\cos\frac{1}{2}I}-(gN+p). \quad . \quad (313)$$

Also, from the figure, $AD=GD\dfrac{\sin F}{\sin\ (90-\frac{1}{2}I)}$, or

$$AH=[gN+p+k+R\tan\ (\tfrac{1}{2}I-F)]\frac{\sin F}{\cos\ \frac{1}{2}I}+R\ \text{exsec}\ (\tfrac{1}{2}I-F). \quad (314)$$

Second Case. *Frog-numbers Unequal.*

Let the frog-number at $C$ be $N$ (the angle $F$) and that at $B$ be $N'$ (with angle $F'$). The angle at the center of the connecting curve is now $I-F-F'$. Extend $ED$ to intersect $AC$ at $L$ (not shown). In triangle $LGD$ the side $GD=gN+p+k+R\tan\frac{1}{2}(I-F-F')$, angle $GDL=I-F-F'$ and angle $LGD=F$. Solve for $GL=m$ and $LD=t$.

In triangle $ELA$, $EL$ and all angles are now known. Solve for $LA$ and $AE$. Then

$$CA=LA+m-(gN+p), \quad \text{and} \quad AB=AE-(p'+gN'). \quad (315)$$

By connecting up the tracks in two adjacent angles a Y is formed and trains can be turned completely around for one track or diverted to the other track in one direction. By connecting the tracks in all four angles wyes for all tracks are formed.

**206. Given the Intersection Angle, *I*, Made by a Straight and a Curved Track, the Radius, *R*, of Intersecting Curve, *R′*, the Radius of a Curve uniting the Two tracks, and the Frog-Angles, *F*, and *F′* (either equal or unequal), to Find the Location of the Frog-points and the Central Angle of Joining Curve.**

In Fig. 107, $DBA$ is the center line of straight track and $SAC$ the center line of curved track. The angle $I$ is measured in the field. If $I$ is large, a transfer track may be inserted in any one or all of the four angles formed by the intersecting tracks, and in the latter case a system of wyes formed; but if $I$ is small only two such joining curves may be inserted, one of which will be as in the figure and the other in the opposite angle. If $I$ is very small, this latter position may necessitate so long a connection, because of the clearness required at the *P.I.* that it may not be desirable.

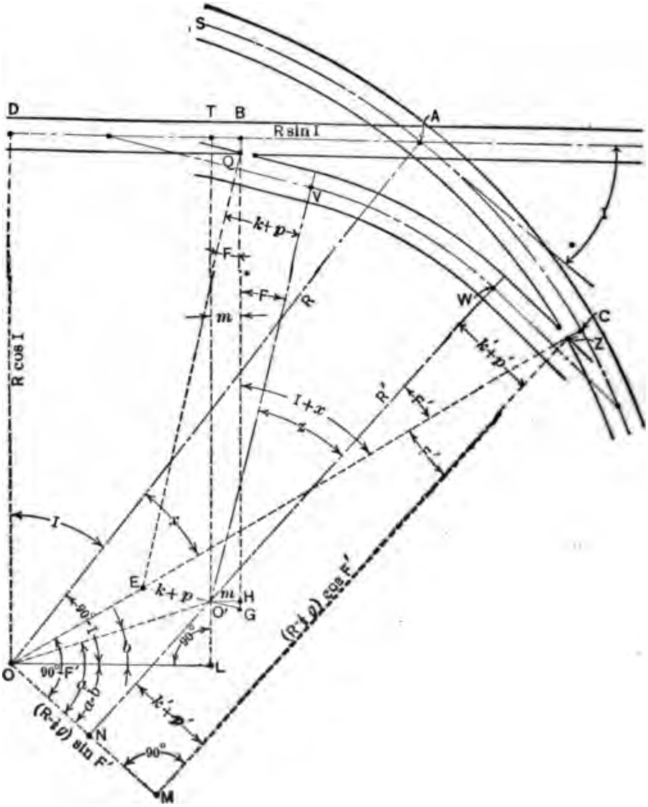


FIG. 107.

For the case shown $I$, $R$, $R'$, $F$, and $F'$ are known. The arcs $AC$ and $VW$, and also the distance $AB$, are to be found. Let the construction lines be as shown. $Q$ and $Z$ are the theoretical points of frogs.

In the right triangle $OZM$, $OM = (R - \frac{1}{2}g) \sin F'$ and $ZM = (R - \frac{1}{2}g) \cos F'$.

In the right triangle $OO'N$, $ON=OM-k'-p'$, and $O'N=MZ-(R'+\frac{1}{2}g)$. Hence we find

$$\tan a=\frac{O'N}{ON}, \quad \text{and} \quad OO'=ON \sec a.$$

From the right traingle $OAD$, $OD=R\cos I$ and $AD=R\sin I$.

In the right triangle $QEG$, $QE=R'+\frac{1}{2}g$ and the angle at $Q$ equals $F$. Therefore $EG=(R'+\frac{1}{2}g)\tan F$ and $QG=(R'+\frac{1}{2}g)\sec F$.

In triangle $O'HG$, right angled at $H$, angle $HO'G=F$, and $O'G=EG-(k+p)$. Therefore $O'H=m=O'G\cos F$ and $HG=l=O'G\sin F$.

In the right triangle $OO'L$, $OO'$ is known, and $O'L=LT-TO'=OD-HB=OD-[(QG+\frac{1}{2}g)-HG]$, or, inserting values,

$$O'L=R\cos I-(R'+\tfrac{1}{2}g)\sec F-\tfrac{1}{2}g-l.$$

Therefore

$$\sin b=\frac{O'L}{O'O}, \quad \text{and} \quad OL=OO'\cos b.$$

Now, from the figure,

$$x=[a-b+(90-I)]-(90-F')=a-b-I+F', \quad . \quad (316)$$

and the length of the curve $AC$, in chains, is $x$ divided by $D$. The actual frog-point is therefore to be set at a distance equal to arc $AC-p'$ from $A$.

The length of $AB$ equals $AD-DB$, or

$$AB=R\sin I-OL-m, \quad . \quad . \quad . \quad . \quad (317)$$

and the actual frog-point is set at a distance $AB-p$ from $A$.

The angle $VO'W=z=I+x-F-F'$, when divided by $D'$, gives the length of the connecting curve in chains.

**207. Given the Angle $I$ and the Radii $R$ and $R_1$ of Two Intersecting Curved Tracks, the Frog-angles $F$ and $F'$, and the Radius $R_2$ of Connecting Track, to Find the Location of the Actual Frog-points on the Intersecting Curves and the Central Angles of the Required Arcs.**

As in the case of the intersection of a straight and a curved track, four joining tracks may be inserted if the angle $I$ is large, or two (and possibly only one) if the angle is small. Let Fig. 108 represent the case where the joining curve is inserted in the most favorable angle. By following the same treatment as given for this case, there should be no difficulty with the solution when the joining curve lies in one of the other angles. The construction lines and notation of the figure are self-explanatory.

Two sides and the included angle are known in triangle $AOO_1$. Solve for the angles $a$ and $b$ and the side $OO_1$.

In the right triangle $QOE$, $QO$, and the angle $EQO$ are known. Hence $OE=(R-\frac{1}{2}g)\sin F$, and $QE=(R-\frac{1}{2}g)\cos F$.

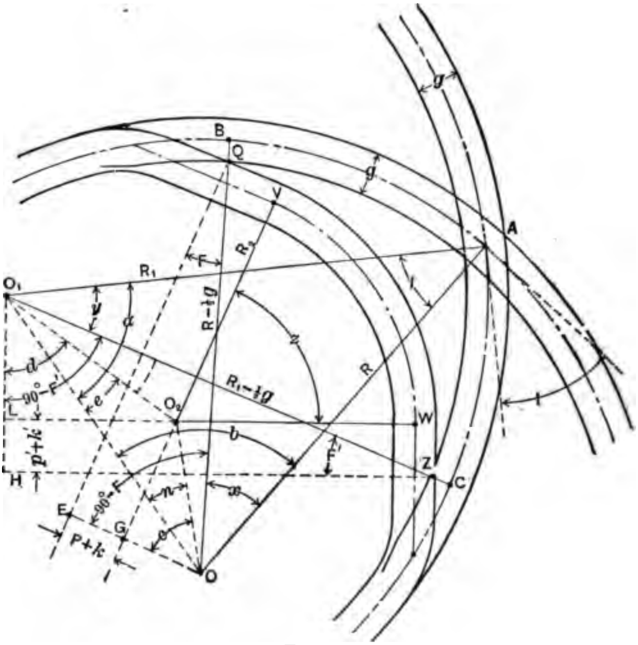


FIG. 108.

In the right triangle $OO_2G$, $OG=OE-(k+p)$, and $O_2G=EQ-(R_2+\frac{1}{2}g)$, being known, we get $\tan c=\frac{O_2G}{OG}$, and $OO_2=OG\sec c$.

In the right triangle $ZO_1H$, the side $ZO_1$ and angle $O_1ZH$ are known. Therefore $O_1H=(R_1-\frac{1}{2}g)\sin F'$, and $ZH=(R_1-\frac{1}{2}g)\cos F'$.

In the right triangle $O_1O_2L$, $O_2L=ZH-(R_2+\frac{1}{2}g)$, and $O_1L=O_1H-(k'+p')$ are known. Therefore $\tan d=\frac{O_2L}{O_1L}$, and $O_1O_2=O_1L\sec d$.

In the triangle $OO_1O_2$, all three sides are known. Solve for the angles $e$ and $n$. Then

$$x = b - n + c - (90^\circ - F) = b + c + F - n - 90^\circ. \quad . \quad (318)$$

Also $$y = a - e + d + F' - 90^\circ. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (320)$$

The arc $AB$, in chains, equals $x$ divided by $D$ and the actual frog-point is set at a distance $AB - p$ from $A$. The arc $AC$, in chains, equals $y$ divided by $D_1$ and the actual frog-point is set at a distance $AC - p'$ from $A$.

The angle at the center of the connecting curve is

$$z = I + x + y - F - F', \quad . \quad . \quad . \quad . \quad . \quad . \quad (321)$$

and the length of its arc is $z$ divided by $D_2$, measured in chains.

### 208. To Locate a Y when One Leg is a Straight Line.

In Fig. 109 let $HE$ be the straight line, and $A$ the position one of the frogs must occupy. Let the numbers, and therefore the angles $F$, $F_1$, and $F_2$, be known and also the radii $R$ and $R_1$. It is required to find the distance $AB$ between actual frog-points on the straight track and the central angles $x$ and $y$ of the other two legs of the wye. Let $w$, $w_1$, and $w_2$ be the known spreads of the respective frogs, at their heels.

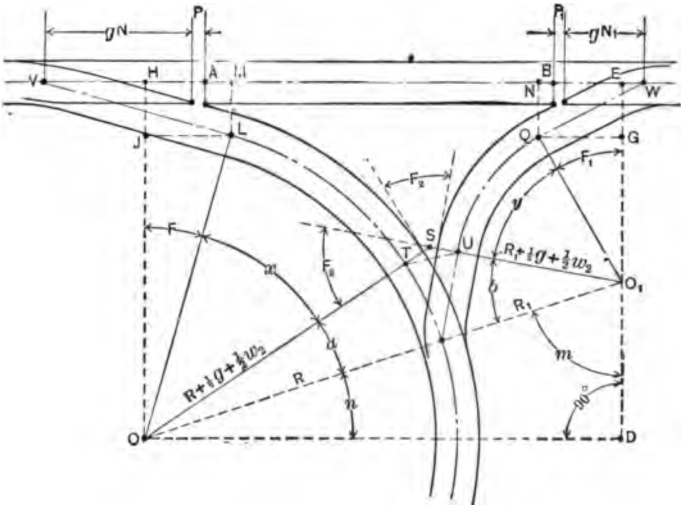


FIG. 109.

In triangle $OSO_1$, two sides and the included angle are known. Solve for $OO_1$ and the angles $a$ and $b$.

In the right triangle $O_1GQ$, $O_1G = R_1 \cos F_1$ and $QG = R_1 \sin F_1$.

In the right triangle $OJL$, $OJ = R \cos F$ and $JL = R \sin F$.

In the right triangle $VLM$, $VL = gN + p + k$ and the angle at $V$ equals $F$. Therefore $LM = VL \sin F$ and $VM = VL \cos F$.

In the right triangle $QNW$, $QW = gN_1 + p_1 + k_1$. Therefore $QN = QW \sin F_1$, and $NW = QW \cos F_1$.

By addition, $OH = OJ + JH = OJ + LM$, and $O_1E = O_1G + GE = O_1G + QN$. Hence, $OH$ and $O_1E$ become known, and therefore $O_1D = OH - O_1E$.

Hence, from the right triangle $OO_1D$,

$$\cos m = \frac{O_1D}{OO_1}, \quad \text{and} \quad n = 90° - m.$$

Also,

$$OD = HE = OO_1 \cos n. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (322)$$

From the figure,

$$\left.\begin{array}{l} x = 90° - (n + a + F) \\ \text{and} \\ y = 180° - (m + b + F_1) \end{array}\right\} \quad . \quad . \quad . \quad . \qquad (323)$$

Also $MN = OD - (JL + QG)$, and $VW = MN + VM + NW$. Hence

$$AB = VW - [(gN + p) + (gN_1 + p_1)]. \quad . \quad . \qquad (324)$$

Set up transit at $L$ with plate vernier set to $F°$ back of zero when line of sight lies along a line $JL$ parallel to $AB$. Deflect to zero and line of sight will be parallel to turnout leg of frog, and tangent to the curve $LT$ at $L$. Run the curve to $T$, covering the angle $x$. Measure $MN$ or $AB$ and set up transit at $Q$, after which run arc $QU$, having the central angle $y$. As a check $TU = 2 . \frac{1}{2}(g + w_2) \cos \frac{1}{2}F_2$.

Either leg of $Y$ may be a branch line, or this branch may be straight beyond the head-block.

### 209. To Locate a Y when the Three Branches are Curved and Convex toward Each Other.

For this case the three radii, $R$, $R_1$, and $R_2$, are known; also the three frog-angles, $F$, $F_1$, and $F_2$, and the location of one of the actual frog-points, as $A$, in Fig. 110. The central angles, $x$ $y$, and $z$ are to be found in order to locate the frog-points $B$ and $C$.

$O$, $O_1$, and $O_2$ are the centers of the three branches of the wye, respectively, which curves are tangent to the frogs at their heels. The lines of the frogs may be extended, if desired, so as to insert frog-tangents of any desired length, provided these are equal on both sides of the same frog. Let the radii be extended so as to meet in pairs at *E*, *G*, and *H*.

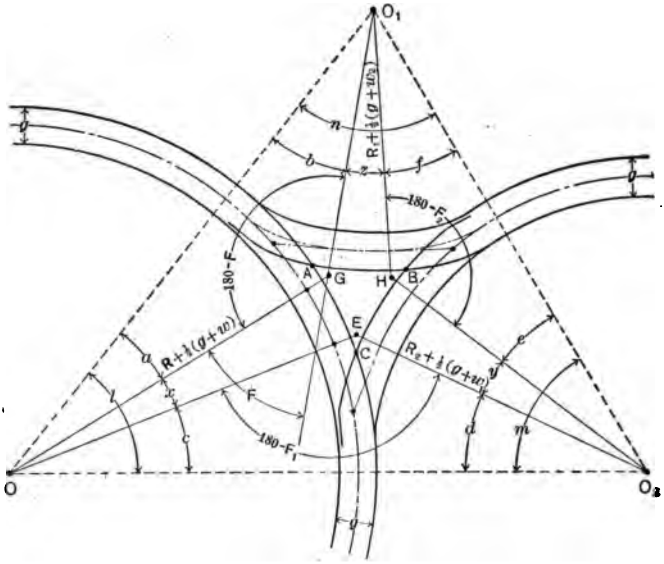


FIG. 110.

In the triangle $OO_1G$, side $OG=R+\frac{1}{2}(g+w)$, and side $O_1G=R_1+\frac{1}{2}(g+w)$, while the included angle equals 180° − *F*. Solve for angles *a* and *b* and side $OO_1$. Angle $b=F-a$.

In triangle $OEO_2$, $OE=R+\frac{1}{2}(g+w_1)$ and $O_2E=R_2+\frac{1}{2}(g+w_1)$. Solve for angles *c* and *d*, and side $OO_2$.

In triangle $O_1O_2H$, $O_1H=R_1+\frac{1}{2}(g+w_2)$, $O_2H=R_2+\frac{1}{2}(g+w_2)$. Solve for angles *e* and *f* and the side $O_1O_2$.

In the triangle $OO_1O_2$ the three sides are now known and the three angles may be found. Any one of the usual methods may be used. The following will answer:

Let the half sum of the three sides be *s*, then

$$\cos\tfrac{1}{2}l=\sqrt{\frac{s(s-O_1O_2)}{OO_1\times OO_2}}. \quad . \quad . \quad . \quad . \quad . \qquad (325)$$

Angles $m$ and $n$ are found in like manner. Then,

$$x = l - (a+c), \quad y = m - (d+e), \quad z = n - (f+b). \quad . \quad (326)$$

The field work necessary is now apparent.

**210. To Locate a Y when One Branch is Concave to the Other Two.**

The data given are the same as when the three branches are convex to each other. Let Fig. 111 represent this case.

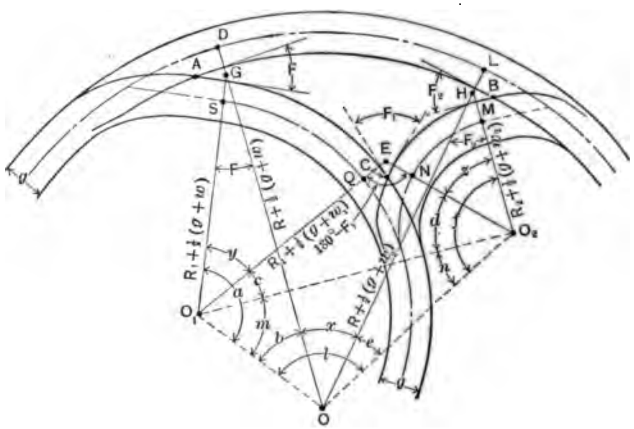


FIG. 111.

The method of solution is identical with that followed in the preceding section. Angles $a$ and $b$ and the side $O_1O$ are found from triangle $OO_1G$; angles $c$ and $d$ and side $O_1O_2$ are found from triangle $O_1O_2E$; angles $e$ and $f$ and side $OO_2$ from triangle $OO_2H$.

In the triangle $OO_1O_2$, three sides are now known, from which the angles $l$, $m$, and $n$ may be found. Thus

$$\cos \tfrac{1}{2}m = \sqrt{\frac{s(s-OO_2)}{OO_1 \times O_1O_2}}, \quad . \quad . \quad . \quad . \quad . \quad (327)$$

Angles $l$ and $n$ are found in like manner. Then the central angles of the arcs which comprise the three branches of the wye will be

$$x = l - (b+e); \quad y = a - (c+m); \quad z = f - (n+d). \quad . \quad (328)$$

The field work required will now be apparent.

## ARTICLE 17. CROSSING-FROGS AND CROSSING-SLIPS.

### A. Crossing-frogs.

**211.** When two tracks intersect each other four *crossing-frogs* are required at the intersection of the two sets of rails. The four frogs are sometimes called a set of crossing-frogs.

**212. To Find the Length of Rails Intercepted between two Intersecting Straight Tracks when the Angle of Intersection and the Two Gauges are given.**

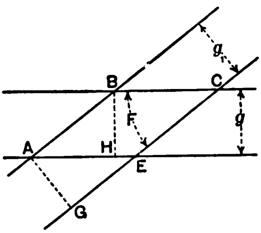


FIG. 112.

In Fig. 112, from triangle $ABH$,

$$AB = EC = g \operatorname{cosec} F; \qquad (329)$$

and from triangle $AEG$,

$$AE = BC = g_1 \operatorname{cosec} F. \qquad (330)$$

**213. Given the Angle of Intersection, $a$, made by the Center Lines of a Straight and Curved Track, the Gauges $g_1$ and $g$, to Find the Angles of the Set of Crossing-frogs.**

In Fig. 113, from the triangles $OBK$ and $OAH$,

$$(R + \tfrac{1}{2}g) \cos F = R \cos a + \tfrac{1}{2}g_1.$$

$$\therefore \cos F = \frac{R \cos a + \frac{1}{2}g_1}{R + \frac{1}{2}g}. \quad . \quad (331)$$

In like manner,

$$\cos F_1 = \frac{R \cos a - \frac{1}{2}g_1}{R + \frac{1}{2}g}. \quad . \quad (332)$$

$$\cos F_2 = \frac{R \cos a - \frac{1}{2}g_1}{R - \frac{1}{2}g}. \quad . \quad (333)$$

$$\cos F_3 = \frac{R \cos a + \frac{1}{2}g_1}{R - \frac{1}{2}g}. \quad . \quad (334)$$

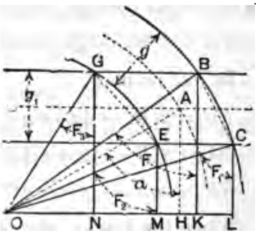


FIG. 113.

From triangle $BOC$ to find the chord $BC$.

$$BC = 2(R + \tfrac{1}{2}g) \sin \tfrac{1}{2}(F_{.} - F). \quad . \quad . \quad . \quad (335)$$

Similarly,

$$GE = 2(R - \tfrac{1}{2}g) \sin \tfrac{1}{2}(F_2 - F_3). \quad . \quad . \quad . \quad . \quad . \quad . \qquad (336)$$

From triangles $EOM$ and $COL$, we have

$$EC = ML = (R + \tfrac{1}{2}g) \sin F_1 - (R - \tfrac{1}{2}g) \sin F_2. \qquad (337)$$

In like manner,

$$GB = NK = (R + \tfrac{1}{2}g) \sin F - (R - \tfrac{1}{2}g) \sin F_3. \qquad (338)$$

**214. Given the Angle of Intersection, $a$, made by the Center Lines of Two Curved Tracks, their Gauges, $g$ and $g_1$, to Find the Angles of the Crossing-frogs.**

In Fig. 114, $OA = R$, $O_1A = R_1$, and angle $OAO_1 = a$ of the triangle $OAO_1$ are given; whence $OO_1$ may be determined.

In triangle $OBO_1$ the side $OB = R + \tfrac{1}{2}g$, $O_1B = R_1 + \tfrac{1}{2}g_1$, and $OO_1 = k$ are known, from which we can determine the angle $OBO_1 = F$.

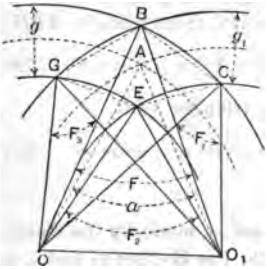


FIG. 114.

In like manner from the triangle $OCO_1$ determine $F_1$, and from triangle $OEO_1$ find $F_2$. $F_3$ may be found from triangle $OGO_1$.

To find the chord $GB$ first find angle $BO_1O$ from triangle $BO_1O$, and angle $GO_1O$ from triangle $GO_1O$; then

$$GB = 2(R_1 + \tfrac{1}{2}g_1) \sin \tfrac{1}{2}GO_1B. \qquad (339)$$

In like manner,

$$EC = 2(R_1 - \tfrac{1}{2}g_1) \sin \tfrac{1}{2}EO_1C, \qquad (340)$$

$$BC = 2(R + \tfrac{1}{2}g) \sin \tfrac{1}{2}BOC, \quad . \qquad (341)$$

$$GE = 2(R - \tfrac{1}{2}g) \sin \tfrac{1}{2}GOE. \quad . \qquad (342)$$

When the tracks intersect, as in Fig. 115, the solution is evidently similar to the foregoing.

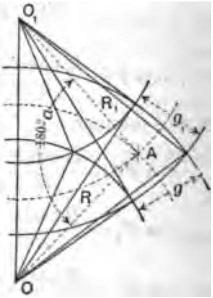


FIG. 115.

(See **219** in connection with **213** and **214**)

### *B. Crossing-slips.*

**215. A Crossing-slip** is an arrangement of switch-rails, in connection with a set of crossing-frogs, to connect two tracks intersecting at a small angle.

**216. Given the Angle of Intersection of Two Straight Tracks, to Find the Length and Radii of Curvature of Slip-rails.**

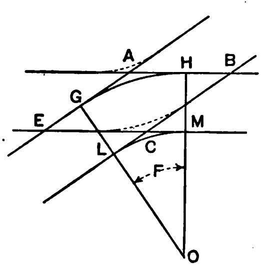


FIG. 116.

In Fig. 116 determine $EA$ and $AB$ by **212**; then assume $GE$ or $BH$ (according as $EA$ is less or greater than $AB$) as small as the crossing-frogs will permit. Draw the radii $HO$ and $GO$; $AH = AG = k$ is the known tangent for the central angle $F$. Hence

$$OG = R + \tfrac{1}{2}g = AH \cot \tfrac{1}{2}F = 2kN, \quad (343)$$

$$OL = R - \tfrac{1}{2}g = 2kN - g. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (344)$$

For the theoretical length of rails,

$$GH = (R + \tfrac{1}{2}g) \times \frac{\pi}{180} \times F^\circ = (R + \tfrac{1}{2}g) \times \frac{F^\circ}{57.3}. \quad . \quad . \quad (345)$$

$$LM = (R - \tfrac{1}{2}g) \times \frac{F^\circ}{57.3}. \quad . \quad . \quad . \quad . \quad . \quad (346)$$

**217. Given the Angle of Intersection made by the Center Lines of a Straight and a Curved Track, to Find the Radii and Length of Slip-rails.**

FIRST CASE.—*Slip-rails inside main curve.*

In Fig. 117 determine the angles $F$ and $F_1$ at $B$ and $C$ by **213.** Then assume $KC$ as small as constructive reasons will permit. Now

$$\sin \tfrac{1}{2}KOC = \frac{\tfrac{1}{2}KC}{R + \tfrac{1}{2}g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (347)$$

$$b = BOK = (F_1 - F) - KOC, \quad . \quad . \quad . \quad (348)$$

$$c = KO_1H = F + b = F_1 - KOC. \quad . \quad . \quad (349)$$

From **129**, formula (100),

$$R_1 + \tfrac{1}{2}g = O_1H = \frac{(R + \tfrac{1}{2}g)(\cos F - \cos c)}{1 - \cos c}. \quad . \quad (350)$$

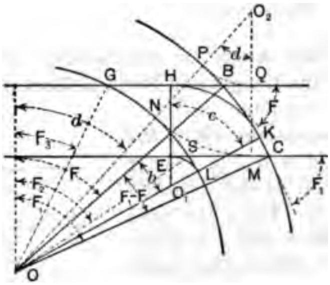


Fig. 117.

For the lengths of slip-rails,

$$HK = (R_1 + \tfrac{1}{2}g) \times \frac{c^\circ}{57.3}. \quad . \quad . \quad . \quad (351)$$

$$EL = (R_1 - \tfrac{1}{2}g) \times \frac{c^\circ}{57.3}. \quad . \quad . \quad . \quad (352)$$

Second Case.—*Slip-rails outside main curve.*

Find the angle $F_2$ at $S$, $F_3$ at $G$, and $GS$ by the methods of **213**. Assume $GN$ as small as constructive reasons permit, and calculate angle $GON$, as in (306) Then $NOS = F_2 - F_3 - GON$, $d = F_3 + GON = F_2 - NOS$. By **129**, formula (106),

$$R_2 + \tfrac{1}{2}g = O_2M = \frac{(R - \tfrac{1}{2}g)(\cos d - \cos F_2)}{1 - \cos d}. \quad . \quad (353)$$

The remainder of the solution is similar to the first case.

**218. Given the Angle of Intersection between the Center Lines of Two Curves, to Find Radii and Length of Slip-rails.**

First Case —*Slip-rails on concave side of curves.*

In Fig. 118 take $LC$ as small as constructive reasons permit. Join $L$ with $O$, then

$$\sin \tfrac{1}{2}LOC = \frac{LC}{2(R + \tfrac{1}{2}g)}. \quad . \quad . \quad . \quad . \quad . \quad (354)$$

Determine angles $COO_1$, $CO_1O$, and side $OO_1$ by **214**. Make $LM = KO_1$; then

$$MO = (R + \tfrac{1}{2}g) - (R_1 + \tfrac{1}{2}g) = R - R_1,$$

and $$MOO_1 = LOC + COO_1.$$

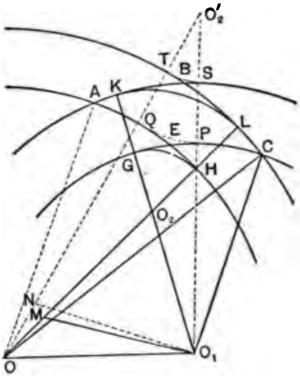


FIG. 118.

In triangle $MOO_1$ two sides and the included angle are now known, and the triangle may be solved. $O_2$ is the center of slip-rail curves.

$$O_2MO_1 = O_2O_1M = MOO_1 + MO_1O,$$

and $$MO_2O_1 = 180 - 2O_2MO_1.$$

From the isosceles triangle $O_1O_2M$, in which $O_1M$ and the three angles are known,

$$MO_2 = \frac{MO_1}{2 \sin \frac{1}{2} MO_2O_1} \quad . \quad . \quad . \quad . \quad . \quad (355)$$

Then

$$R_2 + \tfrac{1}{2}g = O_2L = R_1 + \tfrac{1}{2}g - MO_2, \quad . \quad . \quad . \quad (356)$$

$$R_2 - \tfrac{1}{2}g = O_2H = R_1 - \tfrac{1}{2}g - MO_2. \quad . \quad . \quad . \quad (357)$$

The central angle $KO_2L = MO_2O_1$ being known, $GH$ and $KL$ may be found as in **217**.

SECOND CASE.—*Slip-rails on convex side of curves.*

Let the dotted lines of Fig. 118 represent this case. Assume $AQ$ and compute angle $AOQ$; produce $OQ$ to $O_2'$, the center of slip-rail curve; make $O_2'N = O_2'O_1$. Reasoning as before, find $O_2'N = O_2'O_1$, after which $O_2'S$, $O_2'P$, and the lengths of $TS$ and $QP$ may be found as in the first case.

Should the curves intersect as in Fig. 115, no difficulty will be found in computing the radii and length of slip-rails by following the methods used above.

These methods furnish the *theoretical length* of slip-rails; but as the theoretical and physical switch-points do not coincide, the actual length will be considerably less.

**219.** In computations for crossing-frogs, an additional, and desirable, check is obtained if the diagonals are also determined in Figs. 112, 113, 114, and 115.

In Fig. 112, let $A$ and $C$ be joined, and also $B$ and $E$. From $C$ let fall a perpendicular upon $AE$ produced, intersecting that line at $H$. From $E$ let fall a perpendicular $EK$ upon $AB$. From the triangles so formed we get

$$AC = \sqrt{g^2 + (AE + EC \cos F)^2},$$

and

$$BE = \sqrt{g_1^2 + (AB - AE \cos F)^2}.$$

In Fig. 113 join $G$ with $C$, and $B$ with $E$. Then, from the figure,

$$GC = \sqrt{(OL - ON)^2 + g_1^2},$$

and

$$BE = \sqrt{(OK - OM)^2 + g_1^2}.$$

In Fig. 114 the diagonal $GC$ is found from the triangle $OGC$ in which the sides $OG$ and $OC$ are known and the included angle determined by letting fall perpendiculars $CM$ and $GN$ upon $OO_1$, or $OO_1$ produced, thus yielding triangles $OCM$ and $O_1CM$, whose solution yields angle $COO_1$, and similarly from triangles $OGN$ and $O_1GN$. The angle $GOC$ then equals $GOO_1 - COO_1$.

The solutions for Fig. 115 is similar to that for Fig. 114.

# CHAPTER VI.

## *CONSTRUCTION.*

### ARTICLE 18. DEFINITIONS; GENERAL CONSIDERATIONS; VERTICAL CURVES; SUPERELEVATION OF OUTER RAIL.

**220.** The work of locating the center line having been completed, the field corps is usually disbanded and a new one organized. The **Chief Engineer** still remains in charge, directing the work of construction, passing on bids and estimates, arranging contracts, and attending to such matters of importance as his assistants are unprepared or unauthorized to settle.

**221.** **A Division Engineer** is placed in charge of a considerable length of line, made up of several residencies. To him the resident engineers make reports, and from him receive directions and orders relating to construction. These reports will include monthly estimates, which are forwarded to the chief engineer for inspection and approval. Pay-rolls for the men employed are made out in the office of the division engineer, and forwarded to the chief.

**A Resident Engineer** is placed in charge of a few miles of line, called a **Residency,** and has direct charge of the construction. He should have at least two assistants—a rodman and an axeman—and it will be true economy to allow him also an assistant who can take his place at the instrument and assist in superintending construction.

The resident engineer is usually required to set slope-stakes, locate trestles and other bridges, tunnels, culverts, crossings, and other features preceding track-laying, and to make all measurements upon which estimates are based in determining the compensation of the contractor.

Many roads prefer, especially on maintenance of way, to transpose the terms used above, so that the division engineers report to the resident engineer, whose residency may embrace several divisions.

**222. The Grade-line** is determined from the profile, by stretching a fine thread along the paper and so adjusting its position that the proper relation between cut and fill is obtained, at the same time that the maximum gradient is not exceeded. The cuts and fills should be made as small as possible, at the same time that badly broken or chopped grades are avoided.

**The Gradient** is the rate of change of elevation of grade-line, and is usually expressed in per cents, a 1.2% gradient indicating a rise or fall of 1.2 feet in 100 feet horizontal. When the grade is ascending the gradient is marked plus, and when descending minus.

The word *grade* is frequently used instead of gradient.

The grade-line should be drawn on the profile in red ink, with the points of change marked by a cross or circle, also red. The elevations of these points and the gradients should be written in red above, or below, the grade and surface lines.

The nature of the work and the disposition of material from excavations, and the availability of outside material for embankments will determine whether or not the cuts and fills must balance. If this would necessitate a long haul, it will often be preferable to waste material from excavation and borrow for embankments.

A **Borrow-pit** is an excavation, adjacent to the line, from which material is taken to construct an embankment. It should be separated from the foot of the embankment by a space termed a **Berm**, which should increase with the height of embankment, never falling below a certain minimum width, say six feet. Borrow-pits should be regular in form, with sloping sides and drained so as to prevent water standing in them.

**223. A Cross-section** is a transverse section taken at each station, and at intermediate points where the longitudinal slope changes considerably, the surface between adjacent cross-sections being approximately such as would be generated by a straight line moving on these end sections as directors.

**224. Slope-stakes** are set at stations, to mark the points on cross-sections where the side slope meets the ground-surface. On them the cuts or fills are marked on the inside, while the outsides bear the station-numbers.

No slope-stakes are set at the pluses where cross-sections are taken, unless at the top or foot of bank where an opening is left for a bridge or culvert.

The notes are recorded, however, in order that the contents may be correctly calculated.

**225. A Grade-point** is a point on the intersection of the plane of the road-bed with the ground-surface. If the ground is level transversely, a single stake at the center, marked 0 0, will suffice to locate the point of passage from cut to fill. When the ground is not level transversely, the line of intersection will be oblique to the axis of the road and three grade-stakes are needed, one at the center and one at each side.

If the width of road-bed in excavation differs from the width in embankment, the stake should be set at the edge of the widest base.

### 226. To Find the Grade-point when the Ground Slopes Uniformly between Stations.

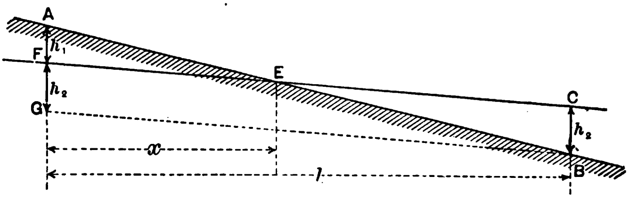


FIG. 119.

In Fig. 119 let $AB$ be the ground-line, $FC$ the grade-line, and $E$ the grade-point. The horizontal distance, $x$, from $A$ to $E$ is required. Let the cut at $A$ be $h_1$, the fill at $B$, $h_2$, and the length of prismoid $l$. Draw $BG$ parallel to $CF$. From the similar triangles $AEF$ and $ABG$

$$x = \frac{lh_1}{h_1 + h_2}. \qquad (358)$$

If the ground does not slope uniformly, the point $E$ must be found by trial, such that the rod-reading equals the difference between height of instrument and elevation of grade.

**227. Vertical Curves.**—The angle formed by the junction of two grade-lines should be rounded off either by substituting several small changes for the one large one, or, preferably, by inserting a regular curve. Where the *algebraic difference* of gradients is less than 0.3% no curve will be needed, while for larger differences the length of vertical curve should vary with that difference, unless the circumstances of the case—such as the proximity of other vertical curves, or a bridge—should prescribe its length. In any case the length may be either assumed, or a given rate of change per station fixed upon and the length computed.

The parabola is especially well adapted for vertical curves, because of the ease with which any correction may be found when one is known, since, as will presently be shown, the corrections vary as the square of the distance from the point of tangency. A second property of this curve enables us readily to find the correction at the vertex, or meeting-point of grade-lines.

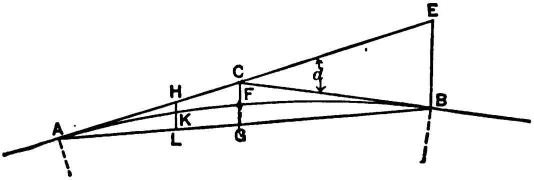


FIG. 120.

In Fig. 120 let *AC* and *CB* be the intersecting grade-lines, and *AFB* the curve substituted for them. Produce *AC* to *E* to meet a vertical through *B*. Draw the vertical *CG*. Then will $CF = FG = m$ by the second property referred to. Since measurements are made horizontally, the similar figures *ACG* and *AEB* furnish the relation $CF = \frac{1}{2}CG = \frac{1}{4}EB$. Calling the *algebraic difference* of gradients $d$, and the length of curve $2l$,

$$m = \frac{1}{4}ld. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

If the rate of change of gradient per station be $a$, it is evident that

$$l = \frac{d}{2a}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

The equation of the parabola referred to $A$ as origin may be written

$$y = \frac{m}{l^2}(2lx - x^2). \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

To find the correction $HK = z$ at a distance $x$ from $A$, we have from the similar triangles $AHL$ and $ACG$,

$$HL = CG\frac{x}{l} = 2m\frac{x}{l}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (d)$$

But $KL = y$, and $z = HL - KL$; or, inserting values,

$$z = \frac{2mx}{l} - \left(\frac{2mx}{l} - \frac{mx^2}{l^2}\right),$$

or

$$z = m\frac{x^2}{l^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (359)$$

Insert the value of $d$ from $(b)$ in $(a)$, and the resultant value of $m$ in (318); then

$$z = \frac{l^2a}{2} \times \frac{x^2}{l^2} = \frac{a}{2}x^2. \quad . \quad . \quad . \quad . \quad . \quad . \quad (359')^*$$

When $x = 1$ station, $z_1 = \frac{1}{2}a$; when $x = 2$ stations, $z_2 = 2a$, etc. It will only be necessary to figure corrections for one-half the curve, as they are the same for corresponding points each side of the vertex. If preferred, however, all corrections may be computed from the first tangent produced.

Example.—A + 0.9% meets a − 0.6% grade at sta. 181, the elevation of which is 91.0 ft. Required the corrections, and corrected grade elevations for points 100 ft. apart.

Here the algebraic difference of gradients is $0.9-(-0.6) = 1.5$. Suppose $a$ be taken as 0.25, or the length of curve as 6 stations.

Formula $(a)$ gives $m = \frac{1}{4} \times 3 \times 1.5 = 1.125$ feet.

At the *P.C.*, sta. 178, $z = 0$; at 179, (359) or (359′) gives $z_1 = 0.125$; at 180, $z_2 = 4 \times 0.125 = .50$. The original and corrected grade elevations are as follows:

| Sta. | 178 | 179 | 180 | 181 | 182 | 183 | 184 |
|---|---|---|---|---|---|---|---|
| Original elevation. | 88.3 | 89.2 | 90.1 | 91.0 | 90.4 | 89.8 | 89.2 |
| Corrections....... | 0.0 | 0.125 | 0.50 | 1.125 | 0.50 | 0.125 | 0.0 |
| Corrected elevat'n | 88.30 | 89.075 | 89.60 | 89.875 | 89.90 | 89.675 | 89.20 |

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* If a circle be taken as the joining curve we may derive (318′) by finding $R$ in terms of $a$, then writing $D = 5730 \div R$, and $n = x$, in formula (36).

EXAMPLE 2.—A + 0.3% meets a + 1.1% grade at sta. 312, whose elevation is 155 0 Find corrections.

Take $a = 0.2$ in this case; then $l = \frac{+0.3 - (+1.1)}{2 \times .2} = 2$ stations. The corrected grade heights, etc., will be as follows:

| Sta. | 310 | 311 | 312 | 313 | 314 |
|---|---|---|---|---|---|
| Original elevation | 154.4 | 154.7 | 155.0 | 156.1 | 157.2 |
| Corrections | 0.0 | 0.1 | 0.4 | 0.1 | 0.0 |
| Corrected elevation | 154.4 | 154.8 | 155.4 | 156.2 | 157.2 |

The reason for adding the corrections in this case will be evident from a figure.

The table below gives the corrections in feet, for certain *algebraic differences* of gradients and lengths of curve, at intervals of 50 ft. each way from the vertex. When the difference of gradients is *plus*, the correction must be *subtracted* from the original grade elevation; when the difference is *minus*, the cor-

TABLE OF CORRECTIONS FOR VERTICAL CURVES.

| Algebraic Difference of Gradients. | Rate of Change of Grade per Station. | Distance from Vertex in Feet. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 |
| 0.3 | 0.075 | 0.15 | 0.08 | 0.04 | 0.01 | 0 | | | | |
| 0.4 | .10 | .20 | .11 | .05 | .01 | 0 | | | | |
| 0.5 | .125 | .25 | .14 | .06 | .02 | 0 | | | | |
| 0.6 | .15 | .30 | .17 | .08 | .02 | 0 | | | | |
| 0.7 | .175 | .35 | .20 | .09 | .02 | 0 | | | | |
| 0.8 | .20 | .40 | .23 | .10 | .03 | 0 | | | | |
| 0.9 | .225 | .45 | .25 | .11 | .03 | 0 | | | | |
| 1.0 | .25 | .50 | .28 | .13 | .03 | 0 | | | | |
| 1.1 | .1833 | .83 | .57 | .37 | .21 | .09 | .02 | 0 | | |
| 1.2 | .20 | .90 | .63 | .40 | .23 | .10 | .03 | 0 | | |
| 1.3 | .2167 | .98 | .68 | .44 | .24 | .11 | .03 | 0 | | |
| 1.4 | .2333 | 1.05 | .73 | .47 | .26 | .12 | .03 | 0 | | |
| 1.5 | .25 | 1.13 | .78 | .50 | .28 | .13 | .03 | 0 | | |
| 1.6 | .2667 | 1.20 | .83 | .53 | .30 | .13 | .03 | 0 | | |
| 1.7 | .2833 | 1.28 | .89 | .57 | .32 | .14 | .04 | 0 | | |
| 1.8 | .30 | 1.35 | .94 | .60 | .34 | .15 | .04 | 0 | | |
| 1.9 | .2375 | 1.90 | 1.46 | 1.07 | .74 | .48 | .27 | .12 | .03 | 0 |
| 2.0 | .25 | 2.00 | 1.53 | 1.13 | .78 | .50 | .28 | .13 | .03 | 0 |
| 2.1 | .2625 | 2.10 | 1.61 | 1.18 | .82 | .53 | .30 | .13 | .03 | 0 |
| 2.2 | .275 | 2.20 | 1.68 | 1.24 | .86 | .55 | .31 | .14 | .03 | 0 |
| 2.3 | .2875 | 2.30 | 1.76 | 1.29 | .90 | .58 | .32 | .14 | .04 | 0 |
| 2.4 | .30 | 2.40 | 1.84 | 1.35 | .94 | .60 | .34 | .15 | .04 | 0 |
| 2.5 | .3125 | 2.50 | 1.91 | 1.41 | .97 | .63 | .35 | .16 | .04 | 0 |
| 2.6 | .325 | 2.60 | 1.99 | 1.46 | 1.02 | .65 | .37 | .16 | .04 | 0 |

rection must be ***added.*** Similar tables for other lengths of curve or differences of gradients may be computed by the engineer, and time in the field saved by their use. In setting grade-stakes, it will be well to set them 50 ft. apart on vertical curves, though to allow for the vertical curve at each regular station will suffice when cross-sectioning.

**228. Elevation of Outer Rail on Curves.**—In 138 it was shown that the superelevation of outer over inner rail might, for standard gauge track, be given, nearly enough, by the formula

$$e = \frac{V^2}{3R}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (134)$$

in which $e$ is the elevation in feet, and $V$ the velocity in miles per hour. Writing $R = \frac{5730}{D}$ in this formula gives

$$e = 0.000058\,V^2D. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (360)$$

The following table has been computed by formula (360).

TABLE OF SUPERELEVATIONS OF OUTER RAIL.

| $V$ in Miles per Hour. | Degree of Curve. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1° | 2° | 3° | 4° | 5° | 6° | 7° | 8° | 9° | 10° | 12° |
| 20 | .02 | .05 | .07 | .09 | .12 | .14 | .16 | .19 | .21 | .23 | .28 |
| 30 | .05 | .10 | .16 | .21 | .26 | .31 | .37 | .42 | .47 | .52 | .63 |
| 40 | .09 | .19 | .28 | .37 | .46 | .56 | .65 | .74 | .84 | .93 | |
| 50 | .15 | .29 | .44 | .58 | .73 | .87 | 1.02 | 1.16 | | | |
| 60 | .21 | .42 | .63 | .84 | 1.04 | 1.25 | | | | | |

Since grade-stakes are set at the edge of base it will be necessary to determine the difference between these elevations and the elevations of center line. Calling this difference $h$, the half-base $b$, and the distance between centers of rail-heads for standard gauge 4.9 feet, we shall have, from similar triangles,

$$h = \frac{b}{4.9}e = 0.2be \text{ (nearly)}. \quad . \quad . \quad . \quad . \quad (361)$$

If the inner rail is required to remain at grade (361) will become

$$h = 0.2be \pm 0.5e, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (361')$$

according as the grade-stake is to be set at outer or inner edge of base.

**Example.**—What will be the value of $h$ when $e = .46$, the base being 14 feet?

By (361), $h = 0.2 \times 7 \times 0.46 = 0.64$ feet. The outside is this much higher than the center, the inside edge this much lower.

The superelevation of outer rail should be computed for the highest speed at which trains are to be run over the curve; the maximum allowed in practice rarely exceeds 8 inches, since a greater elevation would endanger the slow-running freight trains. Even when the theoretical superelevation is given the outer rail, it is more worn than the inner one, either because there are other forces acting, or because of the sliding action of the outer wheel due to imperfect adjustment where the original coning has been destroyed by wear.

Engineers sometimes elevate the outer rail 1 inch per degree up to 3°, and make $e = 3\frac{1}{2}$ inches for a 4° curve, 4 inches for a 5° curve, and $4\frac{1}{2}$ inches for a 6° curve. Still other rules are in use.

If transition-curves are not employed, the difference of elevation is the same from *P.C.* to *P.T.*, fading out to nothing on tangent. The elevation begins on tangent from 100 to 400 feet back of *P.C.*, depending on the amount the outer rail is to be raised.

## ARTICLE 19. VELOCITY HEADS, GRADES, DISTANCE, AND CURVATURE.

**229. The Velocity Head** of a train in motion is the vertical distance through which it would have to drop in order to acquire the velocity at which it is moving at a given instant, with the expenditure of no other effort than that required to overcome friction, curvature, and such other resistances as would have to be overcome in order to maintain a constant speed on a level grade. Frictional resistances are proportional to the weight of the train, but the velocity head is not.

The formula $v^2 = \sqrt{2gh}$ for falling bodies applies here, but in addition the train possesses a certain amount of kinetic energy due to the rotation of its wheels, so that a percentage, sometimes estimated at 5%, is to be added to the value of $h$ found from above formula, though to neglect it will be to stay on the safe side. Taking the acceleration of gravity, $g$, equal to 32.16 feet per second per second, and solving the formula for $h$, we get

$$h = \frac{v^2 \text{ ft. per sec.}}{64.32} = \frac{2.151V^2 \text{ m. per hr.}}{64.32} = 0.03344V^2 \text{ ft.},$$

adding 5% for kinetic energy of wheels, $0.00167V^2$ feet, we get

$$h = 0.03511V^2, \quad \dots\dots \quad (362)$$

The following table gives values of $h$ for velocities varying by one-mile intervals up to 79 miles per hour, computed by (362).

VELOCITY HEADS IN FEET FOR TRAIN VELOCITIES IN MILES PER HOUR.

| Vel. | 0.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.04 | 0.14 | 0.32 | 0.56 | 0.88 | 1.26 | 1.72 | 2.25 | 2.84 |
| 10 | 3.51 | 4.25 | 5.06 | 5.93 | 6.88 | 7.90 | 8.99 | 10.15 | 11.38 | 12.68 |
| 20 | 14.05 | 15.49 | 17.00 | 18.58 | 20.23 | 21.95 | 23.74 | 25.60 | 27.53 | 29.53 |
| 30 | 31.60 | 33.74 | 35.96 | 38.23 | 40.58 | 43.01 | 45.51 | 48.08 | 50.72 | 53.42 |
| 40 | 56.19 | 59.03 | 61.94 | 64.92 | 67.98 | 71.10 | 74.30 | 77.57 | 80.91 | 84.32 |
| 50 | 87.79 | 91.32 | 94.94 | 98.62 | 102.38 | 106.21 | 110.10 | 114.07 | 118.12 | 122.22 |
| 60 | 126.40 | 130.64 | 134.96 | 139.35 | 143.81 | 148.34 | 152.94 | 157.61 | 162.37 | 167.16 |
| 70 | 172.04 | 178.99 | 182.01 | 187.10 | 192.26 | 197.49 | 202.82 | 208.17 | 213.61 | 219.12 |

When a moving train changes speed from $V$ to $V'$ miles per hour, the increase or decrease in the velocity head can be found from formula (362) by substituting $h-h'$ for $h$, or by taking the difference of the velocity heads obtained from the foregoing table. Suppose a train to reach a summit with a velocity of 12 miles per hour, and that the maximum allowable velocity is 32 miles per hour. What will be the total permissible drop on the succeeding down-grade, assuming that the engine is exerting just sufficient force to overcome rolling resistances on a level grade? By formula (362), or by the table, we get

| | | |
|---|---|---|
| Velocity head for 32 miles per hour....... | 35.96 | feet |
| Velocity head for 12 miles per hour....... | 5.06 | " |
| Allowable drop...................... | 30.90 | " |

The distance through which the train will travel while acquiring its additional velocity will depend upon the rate of grade. On a 0.5% grade the distance would be 6180 feet for the case above and on a 1% grade just half of this.

**230. Virtual Grades.**—When a train approaches an ascending grade it possesses an amount of kinetic energy proportional to its weight and the square of its velocity. For the simplest case, which will be very nearly true for ordinary freight trains, the rolling resistances may be taken as being proportional to the weight, so that only the velocity head need be considered in computing the height to which the train would be lifted by virtue of the kinetic energy it possesses. It is assumed that the draw-bar pull of the engine remains constant throughout. The frictional resistance is very nearly constant at about 8 pounds per ton for ordinary freight-train velocities, but in addition there are internal resistances in the engine, impact, and atmospheric resistances, etc. An average value of the draw-bar pull required on a level grade in order to maintain uniform speed may be taken at 10 pounds per short ton. The grade resistance will be proportional to the per cent of grade and equals 20 pounds per ton for a 1% grade, 40 pounds for a 2%, 10 pounds for a 0.5% grade, etc., as a simple diagram similar to Fig. 66 will show.

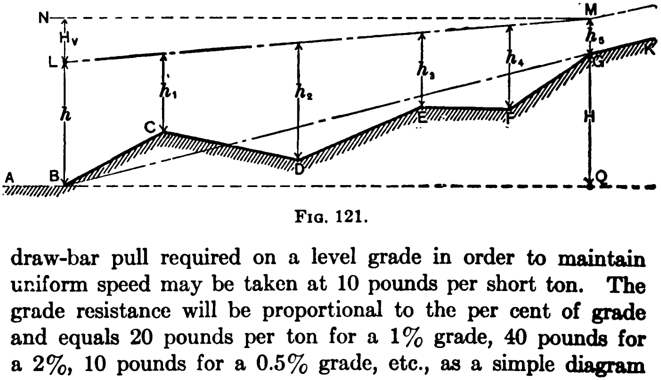


FIG. 121.

The virtual profile may be constructed as follows:

In Fig. 121 let a train reach the foot of a grade at $B$ with a velocity $V$ for which the velocity head $h$ is represented by $BL$ laid off on a perpendicular to the horizontal line $BQ$. Let $BCDEFGK$ represent the actual grade line and $h_5$ the velocity head of the train when it has reached $G$. Let $H=GQ$ be the total net rise between $B$ and $G$. $H_v=LN$ is the total rise of the virtual grade line, $LM$, between $B$ and $G$. From the figure

$$H_v=H+h_5-h.$$

$BG$ represents the uniform grade line which would have had the same effect in retarding the motion of the train while moving from $B$ to $G$ as has the actual grade.

When a stop is made, either on a level or on an inclined grade, the virtual grade line drops to the actual grade line and extra effort must be expended by the motive power in order to acquire the velocity necessary to bring the virtual profile back to the point it would have had if no stop had been made.

The virtual profile shows why the ruling grade may be less than the actual maximum, provided the latter is short.

Traffic is not usually uniform in both directions on a railroad, the greater tonnage generally flowing in one direction, as for a railroad hauling large quantities of heavy freight to a seaport for water shipment, while the return freight is composed of lighter supplies. In such cases the ruling grades, both actual and virtual, should be lower in the direction of heavy traffic than in the reverse direction.

**231. Grades, Distance and Curvature** are factors which vitally affect the cost of construction and operation of railroads, and their influence should be kept constantly in mind, not only by the constructing engineer, but by the engineer who is charged with the duty of making preliminary and location surveys. Heavy grades lessen the cost of construction, but increase the cost of operation, while distance affects both. Curvature increases the distance, but may lessen cost of construction; always it increases cost of operation and danger of accidents. The locating engineer should endeavor to obtain as close an estimate as possible of the probable future traffic, for an increase is almost certain, and he should make his location so as to provide for this as far as possible, consistent with existing conditions and the finances available. Before the grade-lines are laid, these considerations and estimates should be reviewed. Sometimes it is good business to adopt heavy grades and light construction in the beginning where traffic will be light, and later, when the increased traffic justifies, to cut down summits and fill sags while the road is in operation.

**232. Ruling Grades** are those which fix the maximum weight of train which can be hauled by the standard unit of motive power, usually a single engine. For through trains the maximum tonnage per engine is fixed by the maximum tonnage for the heaviest operating division on the line. For locals the tonnage may be varied for each division, but cars may not ordinarily be set out or picked up at will at intermediate points. The maximum grade, if long, is usually the ruling grade, but if short may exceed the latter for reasons mentioned in **230**.

**233. Minor Grades** are those which do not fix a maximum limit for the tonnage which can be hauled by the standard unit of motive power. These may be so light that it is not necessary to shut off the power when running down grade, in order to prevent the train from acquiring a dangerous velocity, or they may be steep enough not only to require the power to be shut off, but to necessitate the application of brakes also.

A loss of efficiency occurs when brakes have to be applied, because kinetic energy is then dissipated in heat. Also the engine must operate intermittently, and not at its greatest efficiency. Even shutting off the power causes a loss for this latter reason. A train on a level grade requires about 10 pounds pull at the draw-bar per ton of train to keep it moving uniformly, and as the effect of grades is to increase the necessary effort of the engine, 20 pounds per ton for each per cent of grade, it is seen that an ascending grade of 0.5% will just double the pull on a level when the same speed is maintained.

**234. Helper Grades, or Pusher Grades,** are those which exceed the ruling grades and are most frequently found on mountain routes. The cost of reducing them to the ruling grade, either by development of the line, where possible, or by heavy cut and fill, may be financially uneconomical, or beyond the resources of the company at the time of construction. A second, and sometimes even a third, engine is attached to the train at these grades to help take the train up the grade. If no helper engines are used, the train must be taken up in sections and the sections set out on a side track until the last one has been brought up. This is not economical, and is impossible where many trains are being operated over that division.

**235. Distance** affects both cost of construction and of maintenance and operation directly as the length of line. The ideal railroad would be straight between terminal points and would have a uniform grade throughout its length. Only for railroads situated on nearly level coastal plains, or in old driedup lake basins, can this ideal be even approximated. Other things being equal, the cost of construction is directly proportional to the length, and therefore, a perfectly straight line is desirable, but in practice this leads to impossible grades or excessive construction cost, or both. Curves are introduced to avoid heavy grades, but these increase the length of the line. If a location can be so made that the line as built oscillates from side to side of the straight line joining the termini, this increase of length is not as great as one would ordinarily expect, however. This is not usually possible, and therefore the location must follow such lines as the topography permits, and which offer the best balance possible of the several factors which the locating engineer must keep constantly in mind.

**236. Curvature** increases the length and consequently the first cost. Also the cost of maintenance, because it is more difficult to maintain track true to line and grade on curves, especially in cuts, than it is on tangents. Curves are especially objectionable if they fall on bridges, but sometimes this can not be avoided. Curves increase train resistance and limit the speed of passenger trains because of the danger of derailment due to centrifugal force. Also they frequently lead to collisions by reasons of interference with the vision of engine men.

Sharp curves are more objectionable than easy ones, because they necessitate greater reduction in speed and consequent loss of energy and time. The use of transition-curves at the ends of easy curves eliminates the necessity for great reduction of speed. The total resistance due to a curve is proportional to the total angle turned, so that it is desirable to keep the total curvature as low as possible, no matter how easy each individual curve may be. It sometimes happens that curves may be so long and so sharp as even to limit the length of train which can be operated, though such a case is comparatively rare. Before the introduction of the consolidation, and later the articulated, type of engine, the degree of a curve had a limit due to the character of the engine wheelbase.

**237. Curve Compensation.**—Where the ruling grade would occur on a curve, if the presence of the latter were disregarded, the curve must be compensated—that is, the grade must be reduced to allow for the resistance due to the curvature. A heavy train rounding a 10° curve will, on the average, assuming the track to be maintained in the same condition as on tangents, encounter about the same amount of resistance due to the curve as it would on a straight level track when constant speed was being maintained, or the equivalent of a 0.5% grade. Therefore, it is customary to reduce the grade on curves, or to "compensate for curvature," the amount of compensation depending upon conditions. The resistance due to curvature is greater, comparatively, for flat curves than for sharp ones, and is also greater as the velocity is lower. On minor grades compensation is not so important, but on ruling or maximum grades it must be provided. When a regular stop falls on a curve, increased compensation must be provided, because of the slow starting velocity. Compensation is more important for heavy freights than for passenger trains.

The following approximate values may be used when making provisions for curvature corrections:

(*a*) On the up-grade side of a regular stop for heavy trains allow 0.1% reduction per degree of curve. On the down-grade side no reduction is necessary because of the stop.

(*b*) As a general rule reduce the grade 0.05% per degree of curve up to about 8 or 10 degrees; for sharper curves make the reduction 0.04% per degree.

(*c*) Where the compensation computed by (*b*) would necessitate serious increase of grade on tangents, use 0.04%, or even 0.03% per degree of curve as the compensation.

Many, if not most, of the railroads located during the earlier stages of railroad construction were built without sufficient time and study being allowed for the surveys, and, as a consequence, much relocation has been done as business grew and economy of operation demanded. By such relocations a great deal of curvature has been eliminated, heavy grades cut down and many down-grades on lines running from a lower to a higher terminus removed.

## ARTICLE 20. EARTHWORK.

### *A. Setting Slope-stakes*

**238. Slope-stakes** are set at the points where the side slopes meet the ground-surface, to mark the limits of the excavation or embankment, and to show the constructor what the cut or fill must be. In Fig. 122, $KAE$ represents the ground-surface, $HBC$ the grade-surface. Let $AB=h$ be the center height. Let $\frac{HL}{KL}=s$ be the side slope, which varies with the nature of the material; for earth-excavation the side slope will average about 1 to 1, so that $s=1$, while for ordinary earth-embankment it will average about $1\frac{1}{2}$ to 1, so that $s=1\frac{1}{2}$. The side height for level sections is the same as the center and may be found for any section, so that the distance $LH$ is required. From the equation defining $s$, $HL=KLs=hs$. Let the base $HC=2b$; the "distance out" from center is

$$d.o = BL = b + hs.$$

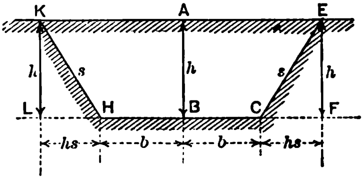


FIG. 122.

**239. Surface Inclined.**—Where the ground slopes transversely the position of the slope-stake cannot be found from the center height unless the slope of the ground-surface, as well as the side slope, is known. The slope-stakes can be most easily and rapidly set by trial.

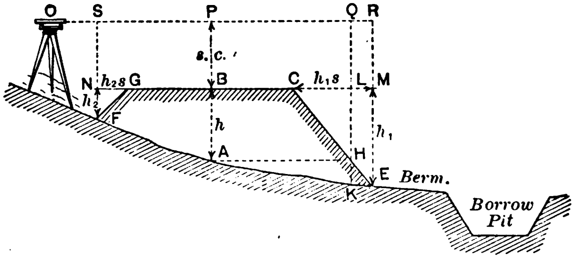


FIG. 123.

In Fig. 123, $FAE$ is the ground-surface, $AB=h$ the fill at the center. We have to find the distances out of $E$ and $F$ from $A$, and the side heights $ME=h_1$, and $NF=h_2$. Let $OP$ represent the plane of the instrument at a height $H.I.$ above the datum, obtained from the known elevation of a bench or turning-point. $PB$ is the height of the plane of the instrument above the grade. Call $PB$ the **Station Constant** ($s.c.$).

The fill at $A$ will evidently equal the rod reading less the station constant. Mark this on the center stake.

Since the ground slopes downward from $A$ to $E$, the distance out will be greater than for a level section, while for $F$, on the higher side, it will be less.

Suppose we take a reading $QK$ at a distance out $= b + hs$; the fill at that point is $LK = QK - QL = r - s.c.$, and the corresponding distance out is $d.o. = b + KL \times s$, which is greater than $AH$, since $LK$ is greater than $h$. If now a reading is taken at the distance out $b + s \times LK$, we shall have a fill greater than $LK$, unless the ground is level from $K$ to $E$, and therefore $b + s \times LK$, the distance out actually used, will be less than that called for by the reading. However we shall have obtained a closer approximation to the position of $E$, and by repetitions of this process may come as close to its true position as the conditions require.

The same thing can be accomplished more rapidly by estimating the fall, by the eye, from $A$ to a point $b + h_1 s$ out, then multiply this estimated fall by the slope and add to $b + hs$. Take a reading $r$ at this distance out; then compute the $d.o.$ for the fill $r - s.c.$ and note if this agrees with the actual $d.o.$ If it does not, make a new trial with this reading as a guide.

For ordinary work the actual and computed distance out should be such that if the rod were held at the computed distance the new distance would not differ more than a tenth from that just computed. The stake is then set at the computed distance out. After a little practice it will be found that the second setting of the rod may usually be made to fall as close to the true position as the limit requires.

When the stake is marked and driven the cut or fill at that point and the distance out are recorded in the notes.

As an example suppose $2b = 14$ feet, $s = 1\frac{1}{2}$ (i.e., slope $1\frac{1}{2}$ to 1), $H.I. = 187.3$, grade elevation $= 184.0$. The station constant is $s.c. = 187.3 - 184.0 = 3.3$. Suppose the rod at center to read 8.5; the fill will be $8.5 - 3.3 = 5.2$, which mark on stake as "$F$. 5.2." The distance out, if section were level, would be $d.o. = 7 + 5.2 \times 1.5 = 14.8$; but suppose the ground rises and we estimate the rise as 1 foot, which multiplied by $s$ gives 1.5 feet to be subtracted from 14.8, since this is on the higher side of center for a section in embankment. Let the reading at 13.3 out be 7.7, which gives a fill of $7.7 - 3.3 = 4.4$ feet, calling for a $d.o. = 7 + 4.4 \times 1.5 = 13.6$. This shows we are too far in, but as a reading further out will be less, giving a correspondingly smaller *d.o.*, we try a reading at 13.5 feet out. Suppose the reading to be 7.6; the fill will be 7.6 − 3.3 = 4.3, calling for a distance out of 13.45 feet, which agrees almost exactly with the trial distance. The stake is marked "*F.* 4.3," and the result recorded in the cross-section book.

On the other side of the section suppose we estimate the fall to be 1.5 feet in 15; we should try a reading at 13.8 + 1.5 × 1.5 = 16.1, say 16.0 feet. Let this reading be 9.0; the fill will be 9.0 − 3.3 = 5.7 feet, calling for a *d.o.* = 7 + 5.7 × 1.5 = 15.6, which shows our reading was taken too far out. Try a reading at 15.4, which suppose 8.9; the fill is 8.9 − 3.3 = 5.6, and the *d.o.* = 7 + 5.6 × 1.5 = 15. 4, which agrees exactly with the trial distance.

In excavation the method of proceeding is the same as in embankment, except that $s$ has generally a different value. For solid rock $s$ is usually $\frac{1}{4}$, that is, the slope is taken as $\frac{1}{4}$ to 1; for loose rock, gravel, and ordinary earth the slope may be taken as 1 to 1. The station constant in cuts is always positive, and the rod reading has to be subtracted from it to obtain the cut. In fills, when the *H.I.* is *greater* than the grade height, the fill equals the difference of the rod reading and the station constant. When the *H.I.* is *less* than the grade height the rod reading plus the *s.c.* gives the fill.

**240. The Notes** may be kept in the form below, which represents one page of the cross-section book. The cut or fill is written above the line, the distance out below. A plus sign indicates a cut, a minus sign a fill

| Sta. | Ground. | Grade. | Left. | Center. | Right. | |
|---|---|---|---|---|---|---|
| 161 | 178.8 | 184.0 | $\frac{-4.4}{13.6}$ | − 5.2 | $\frac{-5.6}{15.4}$ | |
| 162 | 181.6 | 183.0 | $\frac{-0.8}{8.2}$ | − 1.4 | $\frac{-2.0}{10.0}$ | |
| + 20 | 182.2 | − 1.0% | $\frac{0.0}{9.0}$ | − 0.6 | $\frac{-1.0}{8.5}$ | |
| + 48 | 182.5 | | $\frac{+0.9}{9.9}$ | 0.0 | $\frac{-0.4}{7.6}$ | |
| + 66 | 183.5 | | $\frac{+2.4}{11.4}$ | + 1.2 | $\frac{0.0}{9.0}$ | |
| 163 | 185.0 | 182.0 | $\frac{+4.4}{13.4}$ $\frac{+2.8}{10.0}$ | + 3.0 | $\frac{+4.3}{6.1}$ $\frac{+2.6}{11.6}$ | |

**241. Irregular Sections.**—When readings are taken only at the center and sides it is termed a "three-level section." Very irregular ground may require several more readings in order to determine its area; in this case a reading is taken at each change of surface in the section, and the cut or fill, together with the distance out, recorded—the distance being measured from the center to the point where the rod was held in taking the reading.

When the base cuts the ground-surface the section is partly in excavation and partly in embankment, but each side will be staked out in the manner described above. The distance of grade-point from center must be found and recorded.

**242. Staking Out Openings.**—Where openings are to be left for trestles, culverts, and other structures, stakes must be set to mark the limits of the embankment. Stakes marked T. B. are set at the center and sides to fix the place where the top of bank is to end; other stakes, marked F. S., are set at the foot of slope, the plus at which they fall—together with the distance out from center—being recorded in the note-book. The slope of the toe of dump should be the same as the side slope.

**243. Marking Stakes.**—All slope and toe stakes that limit excavation or embankment should be driven with tops inclined outward from the center. The cut or fill is marked on inside in plain figures preceded by the letter C. or F. as being more easily understood by the contractor than the plus and minus signs used in the notes. The reverse side should bear the station number.

**244. Shrinkage—Growth.**—It must be remembered that earthwork in embankment will settle, or *shrink* in volume, even after having been compacted by the feet of the teams during construction. Where the fill is not great, allowance may be made for shrinkage when setting grade-stakes, but in heavy fills allowance should be made when the stakes are set for construction. The proper allowance will vary with the nature of the material, but about 10 per cent will be a fair average. The contract should always specify the amount of shrinkage to be allowed on particular works. If the earth is measured in the borrow-pits, an equivalent allowance should be made, since earth is more compact in embankment than before excavating.

With rock, however, it is found that the volume increases after excavation, and this increase is termed *growth*. The size of the fragments will determine the growth, which will vary from one half to five eighths of the original volume—the larger the fragments the greater the increase. Little or no allowance need be made for settlement when placed in embankment.

**245. Borrow-pits** should be regular in form, particularly if the volume of earth moved is to be measured in the borrow-pit. They should be properly drained to prevent water standing in them and should have an ample **berm** between edge of pit and foot of slope, the width of berm increasing with the height of embankment.

### *B. Areas of Sections.*

**246.** Before the volume of earth in excavation or embankment can be computed the area of each cross-section must be found. To do this divide the section into triangles and trapezoids, find the area of each separately, and take the sum. To shorten the calculations a few simple rules will be deduced.

When the center and side heights are equal we have a **one-level section**; when the center and side heights differ it is a **three-level section**; where the height is found at five places in the section it is a **five-level section**; and so on.

**247. To Find the Area of a Three-level Section.**

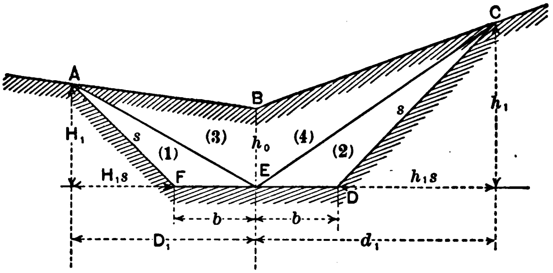


FIG. 124.

In Fig. 124 the area *ABCDF* is required. Draw *EA* and *EC*, dividing the area into four triangles. With the notation of the figure it is seen that triangles (1) and (2) have equal bases *b* and altitudes $H_1$ and $h_1$, while (3) and (4) have the common base $h_0$ and altitudes $D_1 = b + H_1 s$ and $d_1 = b + h_1 s$. By geometry,

$$\text{Area } (1) + (2) = b\frac{H_1 + h_1}{2},$$

$$\text{Area } (3) + (4) = h_0\frac{D_1 + d_1}{2} = h_0\frac{2b + (H_1 + h_1)s}{2}.$$

The area of the whole section is therefore

$$A = b\frac{H_1 + h_1}{2} + h_0\frac{D_1 + d_1}{2} = b\frac{H_1 + h_1}{2} + h_0\frac{2b + (H_1 + h_1)s}{2}. \quad (363)$$

This formula affords an easy method of obtaining the area of a three-level section, and when written in words becomes the following

RULE.—*Multiply the half-sum of the side heights by the half-base and to this add the product of the center height by the half-sum of the distances out; the result will be the area.*

If the linear measurements are in feet, the area will be in square feet.

When $H_1 = h_1 = h_0$, then $D_1 = d_1 = d = b + h_0 s$ and (363) reduces to

$$A = bh_0 + h_0 d = h_0(b + d) = h_0(2b + h_0 s). \quad (364)$$

The section is now a trapezoid or one level section for which (322) may be deduced by the usual rule for the area of a trapezoid.

### 248. Area of Five-level Section.

Fig. 125 represents this case, where we may evidently divide

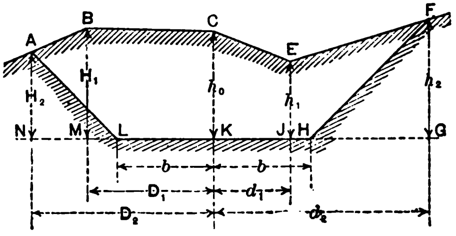
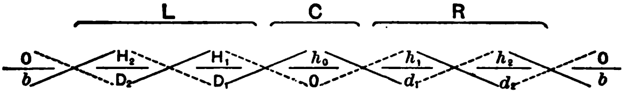


FIG. 125.

the area into triangles and trapezoids, computing the area of each separately and taking their sum for the whole area. The following simpler method may be preferred:

Write the coordinates of successive angular points of the polygons on left and right of center as shown below, the figures above the line being ordinates and those below abscissas. The coordinates of $L$ and $H$ are zero and $b$; those of $K$ both zero.



Beginning at the center, multiply heights by distances out in pairs as indicated by the sloping lines, the products of members connected by full lines being plus and of those connected by dotted lines minus. Half the sum of the products will be the area, thus:

$$A = \frac{1}{2}\left[\begin{pmatrix} h_0D_1+H_1D_2+H_2b \\ +\,h_0d_1+h_1d_2+h_2b \end{pmatrix} - \begin{pmatrix} 0+D_1H_2+0 \\ 0+d_1h_2+0 \end{pmatrix}\right]. \qquad (365)$$

The grouping is symmetrical for areas each side of center, as (323) exhibits; so it will be sufficient to show that the rule is correct for either side. Divide the figure into trapezoids and triangles as shown; then

Area trapezoid $BCKM = \frac{1}{2}(h_0 + H_1)D_1$,
" " $ABMN = \frac{1}{2}(H_1 + H_2)(D_2 - D_1)$,
" triangle $ALN = \frac{1}{2}H_2(D_2 - b)$.

The two trapezoids include the triangle; hence the latter must be subtracted from their sum. Doing this and simplifying, we have

$$A_L = \frac{1}{2}(h_0D_1 + H_1D_2 - D_1H_2 + H_2b),$$

which is the same as results in (323).

**249. General Formula for Areas.**—The method of **248** may be applied to any section no matter how irregular. Suppose there have been $n$ levels taken on one side exclusive of the center height; the notes would appear as below:

$$\frac{h_0}{0} \quad \frac{h_1}{d_1} \quad \frac{h_2}{d_2} \quad \cdots \quad \frac{h_{n-1}}{d_{n-1}} \quad \frac{h_n}{d_n} \quad \frac{0}{b}$$

Expanding in the same manner as in **219**,

$$A_R = \frac{1}{2}[(h_0d_1 + h_1d_2 + \,..\, h_{n-1}d_n + h_nb) - (d_1h_2 + \ldots d_{n-1}h_n)]. \quad (366).$$

To show that (324) gives the true area, consider that we have $n$

trapezoids whose area is positive, and one triangle whose area is negative and equal to $\frac{1}{2}h_n(d_n - b)$.

Writing out the area, we have

$$A_R = \tfrac{1}{2}[(h_0 + h_1)d_1 + (h_1 + h_2)(d_2 - d_1) + \ldots (h_{n-1} + h_n)(d_n - d_{n-1}) - h_n(d_n - b)].$$

Performing the indicated operations and simplifying,

$$A_R = \tfrac{1}{2}[(h_0 d_1 + h_1 d_2 + \ldots + h_{n-1}d_n + h_n b) - (d_1 h_2 \ldots + d_{n-1}h_n),$$

which is the same result obtained in (366).

Evidently $n$ may have any positive integral value.

If preferred, the cross-sections may be plotted on cross-section paper and the area read off by means of a planimeter.

**250. Tables of Areas of Level Sections, and the Three-level Correction.**—Formula (364) may be employed in computing the areas of level sections for any values of $b$ and $s$.

Table XVII gives the areas for a few of these values. When many sections are to be figured it will be well for the engineer to compute the necessary tables, provided he is unable to secure published ones for the particular bases and slopes he is working with. It is not within the scope of this volume to give the variety of tables needed; they are published elsewhere.

The area of three-level sections may be found from the areas of level sections by the aid of a suitable correction. Let the height used in entering the tables of level sections be the mean height of the three-level section, $h_m = \frac{H_1 + 2h_0 + h_1}{4}$; the corresponding area, by (322), is

$$A' = h_m(2b + h_m s) = 2bh_m + h_m^2 s. \quad \ldots \ldots \quad (a)$$

The true area is given by (321):

$$A = b\frac{H_1 + h_1}{2} + h_0 b + h_0\frac{H_1 + h_1}{2}s$$

$$= 2b\frac{H_1 + 2h_0 + h_1}{4} + 2h_0\frac{H_1 + 2h_0 + h_1}{4}s - h_0^2 s$$

$$= 2bh_m + 2h_0 h_m s - h_0^2 s. \quad \ldots \ldots \quad (b)$$

From equations $(a)$ and $(b)$ the correction is

$$c = A' - A = (h_m^2 - 2h_0 h_m + h_0^2)s = (h_m - h_0)^2 s. \quad (367)$$

Table XVIII was computed by (367), and gives values of $c$ which are always positive, and which must be subtracted from the tabular area, found by entering the table with the *mean* height of section, in order to get the true area.

EXAMPLE.—The side heights for a fill having a 14-ft. base and side slopes $1\frac{1}{2}$ to 1 are 8.6 and 16.4 feet, while the center height is 7.7 ft. The mean height is

$$h_m = \frac{8.6 + 2 \times 7.7 + 16.4}{4} = 10.1 \text{ ft.},$$

for which Table XVII gives $A' = 294.4$ sq. ft. For the correction, $h_m - h_0 = 10.1 - 7.7 = 2.4$ ft., for which Table XVIII gives $c = 8.6$ sq. ft.

The true area is now $A = 294.4 - 8.6 = 285.8$ square feet.

### *C. Volume of Earthwork.*

**251.** Cross-sections must be taken at all full stations and at intermediate points, or pluses, where there is a change in longitudinal slope. It will be well in any event to take them so close together that the difference in end heights should not exceed about five feet. The time consumed in making these intermediate measurements will be more than offset by the reliability of the results. A few of the more usual methods of estimating quantities will be given here.

**252. Averaging End Areas.**—This is the easiest of application and therefore the most generally used, but is open to the objection that it gives inaccurate results. However, when bids are based upon it, both parties to the contract agreeing, it would seem to answer as well as any other method.

If $A_1$ and $A_2$ are the end areas and $l$ the length, we shall have

$$V = \frac{A_1 + A_2}{2} l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (368)$$

Stated in words, (326) yields the following

RULE.—*Multiply the half-sum of the end areas by the axial length of prismoid; the result will be the volume.*

If areas are in square feet and length in feet, the volume will be in cubic feet; to reduce to cubic yards divide by 27.

**253. Prismoidal Formula.**—The parallel sections should be so taken that the surface bounding the volume to be measured may be supposed to be generated by a straight line moving on the bounding lines of the sections as directors in such a manner as to return to its original position. Such a figure is called a *prismoid.*

The height of any section intermediate between the end sections is a function of its distance from either end, and the area of that section will be a quadratic function of its distance from either end.

Now we know from mechanics that Simpson's (Newton's) Rule will hold for any function not higher than the third; so for the mean area this rule yields

$$\text{Mean area} = \frac{A_1 + 4A_m + A_2}{6},$$

where $A_1$ and $A_2$ are the end areas, $A_m$ the middle area; hence we have for the volume

$$V = (A_1 + 4A_m + A_2)\frac{l}{6}, \quad . \quad . \quad . \quad (369)$$

in which $l$ is the axial length of prismoid.

The same result may be obtained geometrically by dividing the prismoid into prisms, wedges, and pyramids, and applying the usual rule for volumes.

Let the end areas be $a_1$, $a_2$, $a_1'$, $a_2'$, etc., and the mid-areas $a_m$, $a_m'$, etc.

For the prism $a_1 = a_2 = a_m$; hence the volume is

$$v = a_1 l = (a_1 + 4a_m + a_2)\frac{l}{6}. \quad . \quad . \quad . \quad . \quad (a)$$

For the wedge $a_1' = 2a_m'$ and $a_2' = 0$; therefore

$$v' = a_1'\frac{l}{2} = (a_1' + 4a_m' + a_2')\frac{l}{6}. \quad . \quad . \quad . \quad (b)$$

For the pyramids $a_1'' = 4a_m''$ and $a_2'' = 0$; hence

$$v'' = a_1''\frac{l}{3} = (a_1'' + 4a_m'' + a_2'')\frac{l}{6}. \quad . \quad . \quad (c)$$

Adding (*a*), (*b*), and (*c*), the total volume is

$$V = v + v' + v''$$

$$= [(a_1 + a_1' + a_1'') + 4(a_m + a_m' + a_m'') + (a_2 + a_2' + a_2'')] \cdot \frac{l}{6} \quad . \quad (d)$$

But $\qquad a_1 + a_1' + a_1'' = A_1$

$\qquad a_m + a_m' + a_m'' = A_m,$

and $\qquad a_2 + a_2' + a_2'' = A_2;$

therefore $\qquad V = (A_1 + 4A_m + A_2) \cdot \frac{l}{6},$

the same as (369).

Stated in words there results the following

RULE.—*To the sum of the end areas add four times the mid-area multiply by the length, and divide by* 6. *The result will be the volume.*

To reduce to cubic yards, divide by 27.

Formula (369) contains three terms, the middle area being derived from the cross-section notes for the end sections at the expense of some little trouble. In the attempt to simplify this formula Dr. George Bruce Halsted in 1881 published a two-term prismoidal formula, giving the volume in terms of one base and a section at two thirds of the length of the prismoid, the formula being

$$V = (A_1 + 3A_{\frac{2}{3}})\frac{l}{4} = (3A_{\frac{1}{3}} + A_2)\frac{l}{4}. \quad . \quad . \quad . \quad (370)$$

In 1894 Professor W. H. Echols showed by the aid of higher mathematics that an indefinite number of two-term formulæ might be derived. The same results were established in 1895 by Professor T. U. Taylor by elementary mathematics.

None of these two-term formulæ have so far been placed in a form suitable for application to earthwork measurement, owing to the difficulty of finding the area of the auxiliary section.

In fact the only objection to the use of (327) is the loss of time required in obtaining the mid-area and the uncertainty as to its accuracy in the case of very irregular sections.

For three-level ground we may construct a section having heights that are means between corresponding end heights, but for very irregular sections there may be uncertainty as to what heights must be averaged to obtain the mid section heights. For any other than the mid-sections the heights are obtained with more difficulty.

**254. Form of Notes.**—The record of areas and volumes may be kept in the form below, which represents the cross-section book, with the necessary columns added.

| Sta. | Ground | Grade. | L. | C. | R. | End areas. | Mid-areas. | Exc. cu yds. | Emb. cu.yds. |
|---|---|---|---|---|---|---|---|---|---|
| 91 | 188.5 | 182.0 | $\frac{+6.2}{15.2}$ | +6.5 | $\frac{+8.9}{17.9}$ | +175.53 | | | |
| | | | $\frac{+4.1}{13.1}$ | +5.3 | $\frac{+7.5}{16.5}$ | | +130.64 | | |
| 92 | 185.4 | 181.0 | $\frac{+2.0}{11.0}$ | +4.1 | $\frac{+6.1}{15.1}$ | +89.96 | | 486.4 | |
| | | | $\frac{+1.0}{10.0}$ | +2.1 | $\frac{+3.0}{12.0}$ | | +41.10 | | |
| 93 | 180.0 | 180.0 | $\frac{0.0}{9.0}$ | 0.0 | $\frac{0.0}{9.0}$ | 0.0 | | 158.8 | |
| | | | $\frac{-2.1}{10.2}$ | −3.0 | $\frac{-4.3}{13.5}$ | | −57.95 | | |
| 94 | 173.0 | 179.0 | $\frac{-4.2}{13.3}$ | −6.0 | $\frac{-8.6}{19.9}$ | −144.40 | | | 232.2 |

If the method of averaging end areas is employed, the column of mid-areas will not be needed, and may even be omitted when computing by the prismoidal formula. In this case the notes for mid-section and the mid-area should be written in red ink.

An office record should be kept in addition to the record in the cross-section book, to which it will not be necessary to transfer the elevations of ground and grade. If preferred, the areas and volumes may be kept only in the office record, omitting them in the cross-section book.

**255. Prismoidal Correction.**—The time and labor required to obtain the area of the mid-section makes the use of the prismoidal formula objectionable; for this reason the method of averaging end areas is most often employed. The difference in the two methods will not be great, provided the difference in end heights is not over 3 or 4 ft.; it should never exceed 5 ft.

When the difference exceeds this a considerable error is introduced by the use of (326). It will generally be sufficient to average end areas and then apply a correction if the result must be free from large errors.

(*a*) **Correction for Level Sections.**—Between two level end sections the volume is made up of one prism, one wedge, and two pyramids. For the prism and wedge the true volume is given by averaging end areas, but for the pyramids the error is easily shown to be

$$\frac{2(H_0 - h_0)(H_0 - h_0)s}{2}\left(\frac{l}{2} - \frac{l}{3}\right) \text{ cubic feet,}$$

or

$$C = (H_0 - h_0)^2 \, s \frac{l}{6 \times 27} \text{ cubic yards.} \quad . \quad . \quad . \quad (371)$$

The table below gives the correction $C$ in cubic yards, computed by (371), for a few values of $H_0 - h_0$, when $s = 1$ and $l = 100$; for any other length and slope multiply by $\frac{ls}{100}$.

TABLE OF PRISMOIDAL CORRECTIONS FOR LEVEL SECTIONS.

| $H_0 - h_0$. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 |
| 1 | 0.6 | 0.7 | 0.9 | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 |
| 2 | 2.5 | 2.7 | 3.0 | 3.3 | 3.6 | 3.9 | 4.2 | 4.5 | 4.8 | 5.2 |
| 3 | 5.6 | 5.9 | 6.3 | 6.7 | 7.1 | 7.6 | 8.0 | 8.5 | 8.9 | 9.4 |
| 4 | 9.9 | 10.4 | 10.9 | 11.4 | 12.0 | 12.5 | 13.1 | 13.6 | 14.2 | 14.8 |
| 5 | 15.4 | 16.1 | 16.7 | 17.3 | 18.0 | 18.7 | 19.4 | 20.1 | 20.8 | 21.5 |
| 6 | 22.2 | 23.0 | 23.7 | 24.5 | 25.3 | 26.1 | 26.9 | 27.7 | 28.5 | 29.4 |
| 7 | 30.2 | 31.1 | 32.0 | 32.9 | 33.8 | 34.7 | 35.7 | 36.6 | 37.6 | 38.5 |
| 8 | 39.5 | 40.5 | 41.5 | 42.5 | 43.6 | 44.6 | 45.7 | 46.7 | 47.8 | 48.9 |
| 9 | 50.0 | 51.1 | 52.2 | 53.4 | 54.5 | 55.7 | 56.9 | 58.1 | 59.3 | 60.5 |
| 10 | 61.7 | 63.0 | 64.2 | 65.5 | 66.8 | 68.1 | 69.4 | 70.7 | 72.0 | 73.3 |
| 11 | 74.7 | 76.1 | 77.4 | 78.8 | 80.2 | 81.6 | 83.1 | 84.5 | 86.0 | 87.4 |
| 12 | 88.9 | 90.4 | 91.9 | 93.4 | 94.9 | 96.5 | 98.0 | 99.6 | 101.1 | 102.7 |
| 13 | 104.3 | 105.9 | 107.6 | 109.2 | 110.8 | 112.5 | 114.2 | 115.9 | 117.6 | 119.3 |
| 14 | 121.0 | 122.7 | 124.5 | 126.2 | 128.0 | 129.8 | 131.6 | 133.4 | 135.2 | 137.0 |
| 15 | 138.9 | 140.7 | 142.6 | 144.5 | 146.4 | 148.3 | 150.2 | 152.2 | 154.1 | 156.1 |

(*b*) **Correction for Three-level Sections.**—Formula (371) or the foregoing table may be used in determining the correction for three-level sections when these sections are somewhat similar and the corresponding heights not very different. A general formula may, however, be derived.

Let the center and side heights at one section be $H_0$, $H_1$, and $H_2$, respectively, and let the distance between slope-stakes be $W = D_1 + D_2$; let the corresponding heights at the other end section be $h_0$, $h_1$, and $h_2$ with a distance between slope-stakes of $w = d_1 + d_2$.

By formula (321) the areas will be:

$$\text{Area at first end} = \frac{b}{2}(H_1 + H_2) + \frac{W}{2}H_0, \quad . \quad . \quad . \quad (a)$$

$$\text{Area at second end} = \frac{b}{2}(h_1+h_2)+\frac{w}{2}h_0, \quad . \ . \ . \quad (b)$$

$$4\times\text{mid area} = 4\left[\frac{b}{2}\left(\frac{H_1+h_1}{2}+\frac{H_2+h_2}{2}\right)+\frac{1}{2}\cdot\frac{W+w}{2}\cdot\frac{H_0+h_0}{2}\right]$$

$$= b(H_1+h_1+H_2+h_2)+(W+w)\frac{H_0+h_0}{2}. \quad . \ . \ . \quad (c)$$

From (*a*), (*b*), and (*c*) the volume by the prismoidal rule is

$$V=\left[\tfrac{3}{2}b(H_1+h_1+H_2+h_2)+W\left(H_0+\frac{h_0}{2}\right)+w\left(h_0+\frac{H_0}{2}\right)\right]\times\frac{l}{6}. \quad (d)$$

From (*a*) and (*b*), by averaging end areas,

$$V'=\left[\frac{b}{2}(H_1+h_1+H_2+h_2)+\frac{WH_0}{2}+\frac{wh_0}{2}\right]\times\frac{l}{2}$$

$$=[\tfrac{3}{2}b(H_1+h_1+H_2+h_2)+\tfrac{3}{2}WH_0+\tfrac{3}{2}wh_0]\times\frac{l}{6}. \quad . \ . \ . \ . \ . \quad (e)$$

From (*d*) and (*e*) the correction is

$$V'-V=\left[\frac{W}{2}(H_0-h_0)+\frac{w}{2}(h_0-H_0)\right]\frac{l}{6}$$

$$=(H_0-h_0)(W-w)\times\frac{l}{12}\text{ cu. ft.} \quad . \ . \quad (372)$$

The correction in cubic yards is

$$C=(H_0-h_0)(W-w)\times\frac{l}{12\times27}; \quad . \ . \ . \quad (373)$$

when $l=100$,

$$C=0.31(H_0-h_0)(W-w). \ . \ . \ . \ . \quad (373^1)$$

This correction may be either positive or negative.

EXAMPLE.—Compute the correction for the two prismoids below

| Sta. | L. | C. | R. |
|---|---|---|---|
| 160.............. | $\frac{+5.4}{14.4}$ | +3.0 | $\frac{+6.6}{15.6}$ |
| 161.............. | $\frac{+10.8}{19.8}$ | +7.0 | $\frac{+11.2}{20.2}$ |
| 162.............. | $\frac{+5.2}{14.2}$ | +9.0 | $\frac{+4.8}{13.8}$ |

For the prismoid between 160 and 161

$$C=(3.0-7.0)(30.0-40.0)\times\frac{100}{12\times27}=+12.3\text{ cu. yds.}$$

For the prismoid between 161 and 162

$$C=(7.0-9.0)(40.0-28.0)\times\frac{100}{12\times27}=-7.4\text{ cu. yds.}$$

When the correction $C$ is positive it must be *subtracted from,* and when negative *added to,* the volume as found by averaging end areas; this is evident from (372). $C$ will be negative when the smaller center height and greater width between slope-stakes occur at the same station, as is illustrated in the example.

The general tendency, however, with the method of averaging end areas is to give volumes that are too large, and the error increases with the square of the difference in end heights, as is evident from (371).

**256.** When the center and sides of roadbed do not pass from cut to fill at the same station we have a volume, part excavation, part embankment, between the same pair of sections, such as is illustrated in Fig. 126.

Between sections $ABC$ and $EDFML$ the solid having bases $ABC$ and $FED$ is embankment, while the pyramid $FML$–$A$ is in excavation.

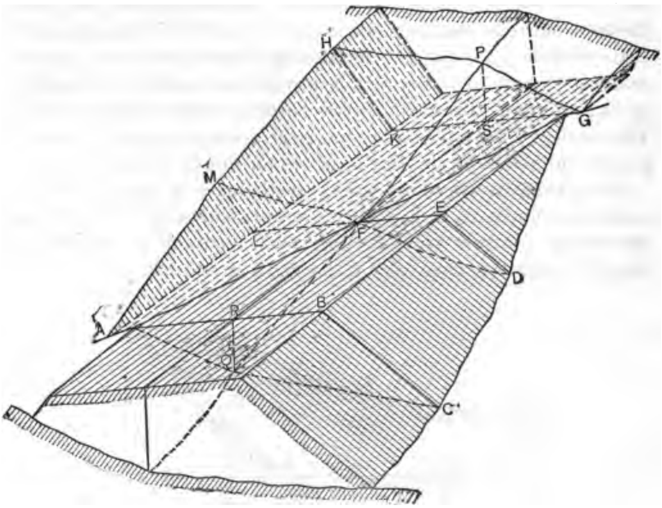


FIG. 126.

For such cases as this the method of averaging end areas is most in error, particularly if the ground have a sharp longitudinal as well as transverse slope. Whatever method is employed, the excavations and embankments must be separately computed.

**257. Tables of Volumes for Level Sections and Equal End Areas** may be used in making preliminary estimates. The average center height for one or more stations is taken from the profile and the volume at once read off from tables, such as Table XIX.

Table XX may be used in finding the volume, after having averaged the end areas, and a correction made by **255** if desired.

**258. Side Ditches** in cuts have a constant cross-section, and hence a constant volume for each full station. Their contents are separately computed and added after the other computations have been made. They need not be shown in cross-section notes.

**259. Earthwork on Curves.**—In computing quantities on curves the end sections are assumed to be parallel, and the axial distance between sections taken as the length of the prismoid. If the volume be taken as generated by a moving section, and the center of gravity of this section lie always on a vertical line passing through the axis, this method gives correct results; otherwise not. The result will be too small or too large according as the center of gravity falls without or within the center line of curve.

If the volumes are computed by averaging end areas, it will be a useless refinement to apply a curvature correction; but if the prismoidal formula is employed, and accuracy is desired, it should be applied, especially if the work be in rock.

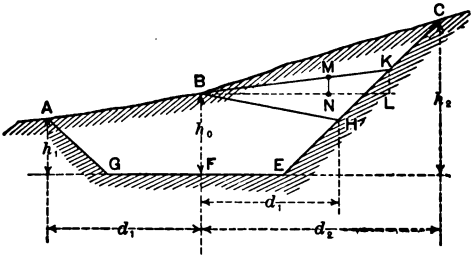


FIG. 127.

To find the curvature correction (*c.c.*) consider Fig. 127, which represents the *mean* section of the prismoid.

The portion *ABHEG* has its center of gravity on the line *BF* (*BH* having the same slope as *BA*); hence the path of its center of gravity will be the same length as the axis of the prismoid, and there will be no error in the computed volume generated by this portion. In the triangle *BCH* draw *BK* to the mid-point of *CH*. The center of gravity of this triangle is at *M*, two thirds of the distance *BK* from *B*. Now, by Guldin's rule (theorem of Pappus) the volume generated equals the area multiplied by the path of the center of gravity, the center of rotation being in the plane of the area.

Draw *BL* horizontal and take *N* on a vertical through *M*; let the angle in degrees at the center be $\theta$.

The volume generated by the triangle *BCH* is

$$V = BCH\frac{\pi\theta^\circ}{180}(R + BN).$$

But the calculated volume is

$$V_0 = BCH \times l = BCH\frac{\pi\theta^\circ}{180}R.$$

Hence the curvature correction will be

$$c.c. = V - V_0 = BCH\frac{\pi\theta^\circ}{180}BN.$$

But $BN = \frac{2}{3}BL = \frac{2}{3}\cdot\frac{d_1 + d_2}{2} = \frac{d_1 + d_2}{3}$

$$\therefore\ c.c. = \frac{\pi}{540}BCH(d_1 + d_2)\theta^\circ = .006BCH(d_1 + d_2)\theta^\circ. \quad (374)$$

When the sections are 100 ft. apart $\theta^\circ = D$ and the correction becomes

$$c.c. = .006BCH(d_1 + d_2)D. \quad . \quad . \quad . \quad . \quad (374')$$

The area of the triangle *BCH* is easily seen to be

$$A = \tfrac{1}{2}[b(h_2 - h_1) + h_0(d_2 - d_1)]. \quad . \quad . \quad (375)$$

If the triangle *BCH* is on the convex side of curve the correction must be added, if on the concave side it must be subtracted.

For light work the correction is small, but for heavy work with steep transverse slope on sharp curves it may be considerable. In practice we may use the middle for the mean area without material error.

EXAMPLE.—Find the correction per station on an 8° curve, 28 ft. base, side slopes 1½ to 1, inside height 10 ft., outside height 30 ft., end sections equal.

## ARTICLE 21. HAUL AND OVERHAUL. THE MASS CURVE.

**260. Haul** is defined as the work done in moving material from excavation to embankment. The unit ordinarily employed is the work done in moving one cubic yard 100 feet horizontally. This unit has been called both the "yard-station" and the "station-yard." It will be here called the *station-yard* (*s.y.*) as being possibly a little easier of verbal expression.

Unit prices are usually based upon a certain maximum length of haul, which length is stated in the specifications which cover a particular contract. This specified distance is called the *length of free-haul*, or the *free-haul distance.* The least value ordinarily assigned is 100 feet and the greatest 1000 feet. Five hundred feet is very generally used.

**261. Overhaul** is defined as the work done in moving material from excavation to embankment through horizontal distances greater than that specified as the limit of free-haul. Its unit is the station-yard, and for this extra haul additional compensation is allowed in the contract. The price paid for overhaul is seldom less than one cent, nor greater than two cents per station-yard. The contractor receives pay for the excavation and for overhaul, but not for the embankment constructed from the material moved unless the specifications provide for payment "both ways," in which case bidders will make their tenders accordingly.

When the payment per cubic yard for overhaul just equals the cost of excavation, the horizontal distance between the initial and final positions of the centers of gravity of the material so moved may be called the *limit of free-haul;* for any greater length of haul it will be cheaper to waste the excavated material and to borrow material within the limit of free-haul for the construction of the embankment, provided such material is available. For any shorter distance the railroad company or owner will find it profitable to pay for overhaul. In cases where contracts are made for payment "both ways" it is optional with the contractor whether he makes the long haul or wastes and borrows all his material.

**262. The Amount of Overhaul** is found by determining the horizontal distance between the initial and final positions of the centers of gravity of the material upon which payment for overhaul is to be made. The contractor is entitled to the benefit of any haul less than the limit of free-haul, so that these limits must first be determined from the cross-section notes, though sometimes it may be done approximately from the profile. The engineer should set stakes to mark these points. Next he must determine the positions, from his notes, of the centers of gravity of the mass to be moved and as finally deposited, and this distance, less the limit of free-haul, when multiplied by the number of cubic yards, will be the amount of overhaul. Occasionally engineers figure the distance from center of gravity to center of gravity of the *whole* mass moved, including that within the limits of free-haul, deduct therefrom the value of the limit of free-haul and compute the overhaul by multiplying the resulting distance by the total number of cubic yards which have been moved. This requires every yard to be moved the full limit of free-haul before overhaul begins to run and is not generally understood by contractors, nor taken into account by them when making their proposals. In so far it is not fair to the contractor.

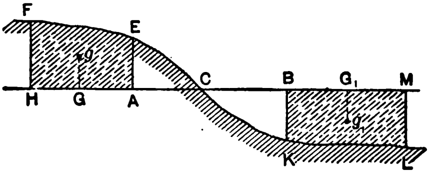


Fig. 128.

In Fig. 128 let $AB$ be the length of free-haul, the points $A$ and $B$ being fixed on the profile so that the volume of $ACE$ equals the volume $CBK$; this may be done by trial computations from the cross-section notes, or in some special cases, approximately from the profile. Let the mass $EFHA$ be removed to $BKLM$, and let the centers of mass in the two positions be $g$ and $g_1$, respectively; the *length* of overhaul to be paid for will be $GG_1 - AB = GA + BG_1$. To find $g$ and $g_1$ accurately, requires that the sum of the moments of the elementary masses equal the moment of the whole mass with respect to any chosen point. It will answer in practice to multiply the volume per station by the distance of its center of mass (found by dividing the station length in the inverse ratio of its end-areas) from some selected point, as $C$, and equate this to the product of the whole mass by the unknown distance of its center of gravity from the same point, then solve for this distance. Indeed, it will answer in most cases to find a point which divides the mass into two equal parts and to treat this as the center of gravity; such a point may be found by trial.

EXAMPLE.—In the figure let $AEFH=6400$ cubic yards, $GA=300$ feet, $G_1B=380$ feet, and the price to be paid for overhaul $1\frac{1}{2}$ cents per station-yard. The additional compensation above the unit price will be $\frac{300+380}{100}\times 6400\times 0.015$ $=\$652.80$.

**263. Cross-haul** is a term applied when the material excavated from different cuts is hauled in both directions over some particular portion of the line. As a general thing it should be considered unnecessary, and, therefore, uneconomic, haul. Sometimes, however, an operating advantage may result from its use which may more than offset the disadvantage of hauling material unnecessarily long distances. This may occur where steam shovels and dump cars are operated. Cross-haul should be avoided and no allowance should be made therefor should the contractor elect to operate in such a way as to involve it, unless this method of haul should be ordered by the engineer to facilitate the work, or for other good reasons.

**264. The Mass Curve** may be employed in computing overhaul graphically, and time and tedious computations saved by its use. Its construction and application are illustrated by Fig. 129.

The irregular line $FECKL$ represents the ground surface seen in profile, and the line $HACBM$ the grade line, which intersects the ground-surface line at $C$. $AB$ represents the length of free-haul, the excavation represented by $CAE$ being just sufficient to form the embankment $CBK$. The volume upon which overhaul is to be computed is represented in excavation by the shaded area $AEFH$. It is required to locate the vertical $ML$ in order that the volume represented by $BMLK$ in embankment may be constructed of the material excavated from $AEFH$.

Let $g$ and $g_1$ be the centers of mass of the material before being excavated and after being placed in embankment. The

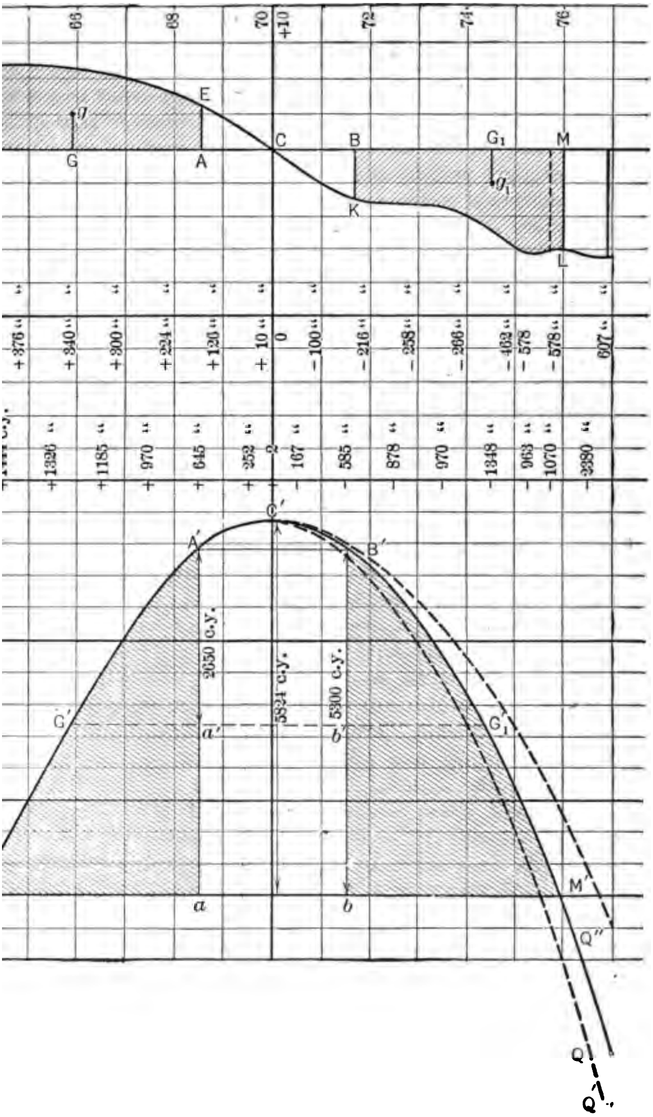

66
68
70 +10
72
74
76
E
g
G
A
C
B
K
G₁
g₁
M
L
+376 "
+340 "
+300 "
+224 "
+120 "
+10 "
0
−100 "
−216 "
−258 "
−266 "
−462 "
−578
−578 "
−607 "
c.y.
+1326 "
+1185 "
+970 "
+645 "
+352 "
+2
−167 "
−585 "
−878 "
−970 "
−1348 "
−963 "
−1070 "
−3380 "
C′
A′
B′
2050 c.y.
5824 c.y.
5300 c.y.
G′
a′
b′
G′₁
a
b
M′
Q″
Q
Q′

FIG. 129.

location of $g$ and $g_1$ and the horizontal distance $GG_1$ between them is required in order that the overhaul may be computed after the volume to be moved has been determined.

On the profile shown in Fig. 129 let $H$ be a point past which no material will be hauled. Through $H$ draw a vertical line and on this vertical select a point $H'$ as the origin of coordinates. At successive station-points on a horizontal through $H'$ erect ordinates equal to the algebraic sum of the quantities between each such station and the initial station $H$. Quantities in excavation and embankment are given opposite algrabaic signs. As here taken, excavation is plus and embankment minus. If preferred, these signs may be reversed, but for the same profile the signs must have the same meaning throughout. The ordinate at $H$ is zero; that at any other point, as Sta. 68, represents, to scale, the total amount of excavation between Stations 64 and 68. The grade-line, represented by the line $HCM$, passes from cut to fill at $C$, which is at Sta. 70+10 in this case. In like manner the ordinate at Sta. 74 represents the algebraic sum of the quantities between Stas. 64 and 74. The ends of adjacent ordinates are then joined by straight lines, or, better still, a smooth curve is passed through them all.

The next step is to determine the location of the points $A$ and $B$ which mark the limits of free-haul. To do this, take the specified length of free-haul to the same scale as horizontal distances have been plotted on the profile, and find, by trial, the points $A'$ and $B'$ on the same horizontal line, and at the same time on the curve, which are distant from each other this distance of specified free-haul. Project $A'$ and $B'$ vertically to $A$ and $B$. The verticals $AE$ and $BK$ mark the limits of free-haul.

Since all the material from excavation is to be utilized in embankment when possible, the vertical $ML$ is located by drawing through $H'$ a horizontal line which cuts the other side of the mass curve at $M'$, and then projecting $M'$ vertically to $M$. $ML$ then defines the limiting position of any material hauled from the excavation represented by the area $AEFH$ to the embankment, which is represented by the area $BKLM$. The equal ordinates $A'a$ and $B'b$ represent the volume of earthwork upon which overhaul is to be computed. The area $A'C'B'$ measures the work done in moving the excavated material from $ACE$ to $CBK$, and the area $H'A'B'M'$ measures the total work done in moving the mass $AEFH$ horizontally to the position it will finally occupy as $BKLM$. The overhaul for this latter mass is, however, measured by the shaded area of the mass diagram, because every cubic yard of this must be moved through the free-haul distance before overhaul begins to run. The unshaded area $A'B'ba$ represents the work done in moving the mass through the horizontal distance between $A$ and $B$.

To find the positions of the centers of gravity, $g$ and $g_1$ of the mass before and after moving, we bisect the ordinate $A'a$, or its equal $B'b$, and project the points $G'$ and $G_1'$, where a horizontal through the mid-point $a'$ cuts the mass curve, vertically to $G$ and $G_1$. The points $g$ and $g_1$ lie on these verticals. The overhaul will then be equal to the quantity $A'a$ multiplied by the sum of the distances $GA$ and $BG_1$, or, stated as a formula,

$$\text{Overhaul} = A'a \times (GG_1 - AB).$$

If the embankment to the right of $ML$ (or of the corresponding vertical in the case of shrinkage or growth) can be entirely filled from a cut lying adjacent to it to the right, the process above described should be used to determine the right-hand limit of the excavation, material from which will be used to construct the embankment.

If both the vertical $HF$ and the corresponding one to the right of the figure are to be determined so as to make the overhaul a minimum we must find, by trial, lines on the two mass curves which are equal in length, which are horizontal, and which have the right-hand end of one and the left-hand end of the other on a common point on the mass curve while their other ends lie also on their respective curves.

It may happen that the quantity of material available for excavation is insufficient to construct the embankment intervening between two grade points, and that some material must be borrowed if the limit of economic haul is not exceeded. Or the material from an excavation may be in excess of th[illegible] needed for the adjacent embankments, in which case ex[illegible] material must be wasted. For such cases compute the limit of economic haul and use this as the value of the closing line $H'M'$ in order to locate both the points $H$ and $M$ on the profile. Do the same for that portion of the mass curve lying to the right of that shown in the figure. The fill or cut between adjacent verticals, such as $ML$ and the next similar vertical, must then be wasted or borrowed according as the excess is excavation or embankment.

Guide stakes should be set for the contractor to mark such points as *H* and *M*, as well as the grade-point *C*, in addition to the cross-section stakes.

**265. The Swell** of earthwork is the increase or decrease in volume of embankment as compared to the volume of the same material before it has been excavated. Ordinary earth will occupy less space when compacted in embankment than it originally did before having been excavated, but with rock the reverse is true, the volume in embankment being greater than the original volume before excavation. The mass diagram just described does not take the swell into account, the assumption being that one cubic yard in its original place will make just one cubic yard when placed in the embankment.

The American Railway Engineering Association recommends the following shrinkage allowances, for both height and width, for green embankments:

Black dirt: trestle filling, 15%, raising under traffic, 5%.
Clay: trestle filling, 10%, raising under traffic, 5%.
Sand: trestle filling, 6%, raising under traffic, 5%.

On levee construction by dredges, and for station work with the wheelbarrow, a shrinkage allowance of 25% is sometimes allowed.

Rock, when blasted out and broken up, will increase in volume from 40% to 60%, depending upon the sizes of the fragments, the smaller sizes yielding the greater growth.

**266. The Application of the Mass Curve to Cases where the Swell is Taken into Account** is illustrated by the dotted and the broken lines of Fig. 129. *C'M'Q* is the mass curve on the assumption of no swell, *C'Q'* the mass curve when shrinkage is allowed for, and *C'Q''* the mass curve on the assumption of growth.

The curve *C'Q'* is obtained by multiplying the yardage for each station successively by the percentage of shrinkage called for in the specifications and adding the resultant quantities to the original volume. By plotting the resulting quantities and joining ends of ordinates as in the case where no shrinkage is provided, the dotted curve results. In like manner the broken curve is obtained for the case of growth, the products obtained by multiplying the quantities computed from the cross-section notes by the percentage of growth being subtracted, because it will require less than one cubic yard in its original position to make one cubic yard when deposited in embankment. For either of these cases the closing line $H'M'$ will have its right-hand end in the curve which applies to the particular case in question. That is, for shrinkage the right-hand end will lie in the curve $C'Q'$ and for growth in the curve $C'Q''$.

Fig. 129 was constructed from the data given on the profile and the two sets of figures below, the upper set being the areas at the points cross-sectioned, and the lower set yardages between consecutive cross-sections. A 10% shirnkage allowance was assumed in plotting the curve $C'Q'$ and a 25% growth for the curve $C'Q''$. This latter rate of growth would correspond to a material composed partly of rock and partly of earth. The proper percentage to use is a matter of experimental determination if a high degree of precision is required, or a matter of judgment if it is assumed, as is frequently the case.

**267. The Limit of Economic Haul** depends upon the unit price paid for earth embankment, provided suitable material may be borrowed within the limit of free-haul, and that space is available for spoil banks, should the quantity of excavation exceed that of embankment, and it depends also upon the unit price paid for overhaul. This limit is simply the distance at which the unit price paid for overhaul equals the unit price paid for embankment. To state it algebraically, let $f$ = limit of free-haul; $h$ = limit of economic haul; $c$ = unit price paid for embankment without overhaul; $n$ = number of cents paid per station-yard for overhaul. Then

$$n(h-f)=c,$$

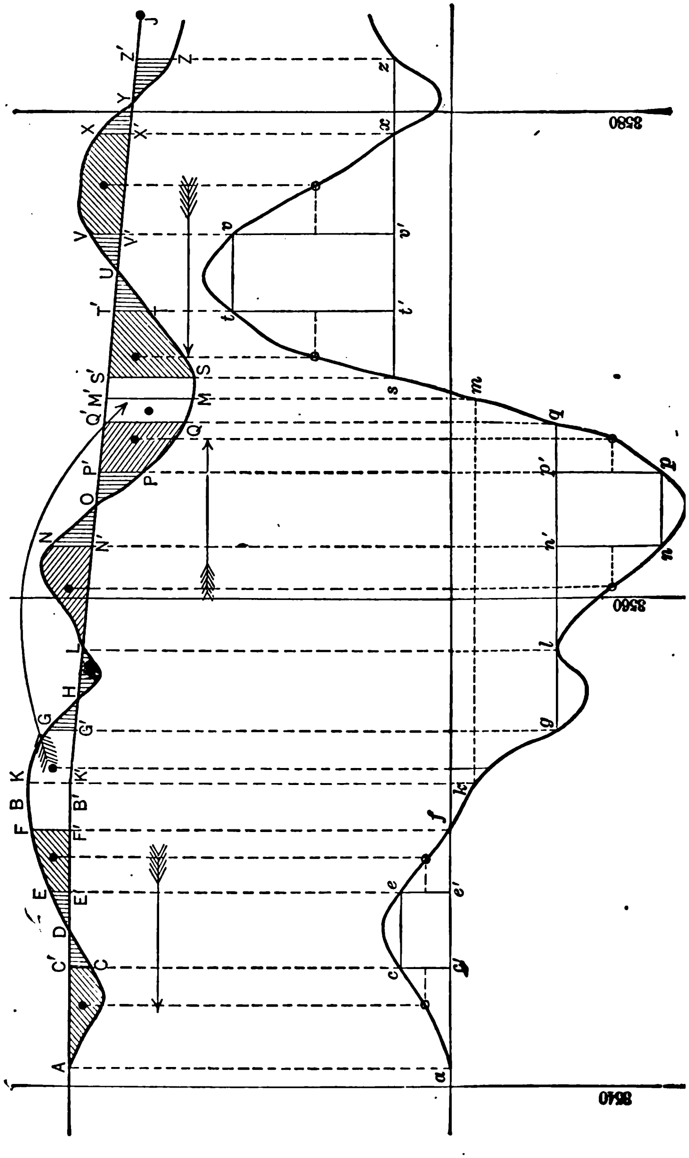
from which

$$h=\frac{c}{n}+f, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \tag{376}$$

EXAMPLE.—Suppose the unit price of embankment is 18 cents per cubic yard, the limit of free-haul 300 feet, and the price paid for overhaul $1\frac{1}{2}$ cents per station-yard.

By (376), $h=\frac{18}{1\frac{1}{2}}+3=12+3=15$ stations.

**268. Application of the Mass Diagram to a Continuous Profile.**—In Fig. 130 the upper curve is the profile of a line between Stations 3538 and 3584 upon which has been drawn the grade line $AB'Z'$. The lower curve is the mass curve, which


A
C
C'
D
E
E'
F
F'
B
B'
K
K'
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G'
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L
N
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f
k
g
l
m
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p
p'
q
s
t
t'
v
v'
x
z
8540
8560
8580

is derived from the successive summations of quantities, beginning with zero at Station 3541 past which no haul is to take place. The points *D*, *H*, *L*, *O*, *U*, and *Y* are grade-points. The limit of free-haul was taken at 300 feet and horizontal lines *ce*, *gl*, *np*, *tv*, and *xz* of this length were drawn between points on the mass curve, as described in **264**, in order to locate the limiting verticals *CC'*, *E'E*, *G'G*, etc. It so happens that the vertical through *l* falls at the grade point *L* in this case. It is evident that there is more than enough material in the cut which lies just to the right of *EE'* to form the embankment *ACC'*. The horizontal *ac'e'f* of the mass diagram is now drawn and the point *f* where it cuts the mass curve is projected to *FF'*, which vertical marks the limit of excavated material which is to be hauled backward to make the fill *ACC'*. There is no embankment to the immediate right of the grade-point *H* in which the remaining portion of the cut, represented by *FGG'F'* on the profile, can be used, as the small embankment between *H* and *L* has been provided for by the cut *GHG'*.

It is evident from the profile that the embankment between the grade-points *O* and *U* will more than take care of all excavation from the cut immediately to the left of *O* and the one immediately to the right of *U*. We therefore draw the horizontal *lq*, and project *q* upward to locate the limiting vertical *QQ'*. In like manner the horizontal *sx* is drawn, and the points *s* and *x* where it intersects the mass curve are projected upward to locate *SS'* and *XX'*, respectively.

The centers of gravity of the masses *ACC'* and *BGG'B'* are found by bisecting *cc'* or *ee'* and drawing a horizontal line through these bisecting points to cut the mass curve, which cutting points are then projected upward to the profile to locate the verticals on which these centers of gravity lie. Round black dots represent the positions of the centers of gravity on the profile. The overhaul distance will then be the horizontal distance between these centers of gravity less the distance of free-haul. In like manner the centers of gravity and overhaul distances of the other masses are found, as indicated in the figure.

There still remains the excavation represented by *FGG'F'*, and the embankment represented by *QSS'Q'*, unprovided for. The first of these may be wasted and the second borrowed within the limits of free-haul, but first let us determine whether or not it will pay to utilize the excavation to make a part or all of the embankment. This will be the case if the limit of economic haul is not exceeded.

The mass diagram shows that the point *f* is lower than the point *s*, and therefore that the embankment at *QSS'Q'* exceeds the excavation at *FGG'F'*, so that, in any event, some material must be borrowed. Now draw a horizontal through *f* to cut the mass curve to the right and if the length of this horizontal does not exceed the limit of economic haul all the excavation may be used in embankment, and only enough borrowed to complete the fill. In the case shown, however, the limit of economic haul is 15 stations, which limit would be exceeded. We therefore locate two points, *k* and *m*, which are distant from each other the limit of economic haul and on the mass curve and also a horizontal line. We then project these points upward to locate the limiting verticals *KK'* and *MM'*. The mass *FKK'F'* must be wasted and the mass *MSS'M'* must be borrowed.

**269. Properties of the Mass Diagram.**—From the preceding figures, and the method of constructing the mass curve, the following properties of the mass diagram result:

(*a*) Ascending portions of the curve indicate excavation and descending portions embankment.

(*b*) Maximum and minimum points on the mass curve, where its tangents are horizontal, occur on verticals through grade-points.

(*c*) The difference in length between any two adjacent verticals of the mass curve is the volume of earthwork between these verticals extended to cut the profile.

(*d*) Excavation equals embankment between two points on the mass curve which are cut by a horizontal line.

(*e*) The area of the mass diagram situated between the curve and a horizontal which cuts it measures the haul between the verticals through these points.

**270. Another Method of Constructing the Mass Curves,** which many engineers prefer, is to draw as many partial mass curves as there are volumes of earthwork which may be moved from excavation to adjoining embankments.

Beginning at a grade-point the quantities to the left of it are added successively and plotted as ordinates, from a horizontal through some point on the vertical through the grade-point, on the proper verticals, and the ends of the ordinates are then joined by a smooth curve. These ordinates may be set off either upward or downward (but usually upward) from the arbitrarily seclected zero horizontal. To the right of the grade-point quantities are summed and plotted in the same manner and in the same direction. This process yields figures similar to Fig. 129 (but usually inverted) if the zero line passes through *C′* instead of *H′*. The limiting vertical is then found just as in **264**.

At each grade-point the above-described process is repeated and a series of detached mass curves obtained instead of a continuous one as in Fig. 130.

## ARTICLE 22. CLEARING AND GRUBBING; DRAINAGE AREAS AND RUN-OFF FORMULAS; CULVERTS AND BRIDGES; TUNNELS.

**271. Clearing and Grubbing.**—Having the center line of the road finally located, actual construction work is begun by first clearing the right of way of all timber growths, though sometimes, for reasons of false economy, only the space to be occupied by the roadway, berms and borrow pits are cleared. For the guidance of the contractor the engineer should define the limits of the right of way either by stakes or by blazing trees on the side lines of the railroad's property. All stumps under embankments and on berms should be grubbed or blasted out to a depth of 18 inches or more, except under high fills, where chopping down the stump to the level of the ground surface may be permitted. In cuts the stumps may be removed as the work of excavation progresses. Borrow pits should be grubbed also, but sometimes this is optional with the contractor, by provision made in the specifications.

A stump puller, ordinarily operated with mules or horses, will often be most economical in removing small stumps. Large stumps may often be removed by dynamite at smaller cost than by grubbing out by hand.

Payments for clearing and grubbing are usually made on an acreage basis, either together or separately. The table below gives the area, in acres, for right of way 100 feet wide for distances varying by single stations from 1 to 60. For 1 mile of right of way 100 feet wide the area is 12.1212+ acres, or closely enough, twelve and one-eighth acres.

TABLE OF AREAS IN ACRES FOR RIGHT OF WAY 100 FEET WIDE AND LENGTHS VARYING FROM 1 TO 60 STATIONS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stations. . . | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Acres. . . . . | 0.23 | 0.46 | 0.69 | 0.92 | 1.15 | 1.38 | 1.61 | 1.84 | 2.07 | 2.30 |
| Stations. . . | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Acres. . . . . | 2.53 | 2.75 | 2.98 | 3.21 | 3.44 | 3.67 | 3.90 | 4.13 | 4.36 | 4.59 |
| Stations. . . | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| Acres. . . . . | 4.82 | 5.05 | 5.28 | 5.51 | 5.74 | 5.97 | 6.20 | 6.43 | 6.66 | 6.89 |
| Stations. . . | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| Acres. . . . . | 7.12 | 7.35 | 7.58 | 7.80 | 8.03 | 8.26 | 8.49 | 8.72 | 8.95 | 9.18 |
| Stations. . . | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
| Acres. . . . . | 9.41 | 9.64 | 9.87 | 10.10 | 10.33 | 10.56 | 10.79 | 11.02 | 11.25 | 11.48 |
| Stations. . . | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| Acres. . . . . | 11.71 | 11.94 | 12.17 | 12.40 | 12.63 | 12.86 | 13.09 | 13.31 | 13.54 | 13.77 |

Following clearing and grubbing the engineer should replace all missing station stakes, hubs and reference-points, and, if these have not been previously so located as to be free from disturbance by the work of clearing and grubbing, should establish bench marks not more that 1500 feet apart for use during construction. One or more such bench marks should be established within easy reach of each opening for a bridge or culvert. Check levels should be run over all benches to insure their required degree of precision.

While the right of way is being cleared, all valuable timber should be piled near the boundary, and brushwood should be burned.

**272. Drainage Areas** should be run out for the purpose of using them as a guide in deciding upon the size of opening to be left for drain pipes, bridges or culverts wherever this is possible. For large streams this is generally not practicable, but the area may frequently be obtained from reliable maps.

In running out drainage areas it will not be necessary to follow the windings of the divides in too great detail. Long shots which "give and take" in such manner as practically to balance areas on each side of same should be used instead of many short lines in order to minimize the labor of computations.

The general surface slopes and the character of the ground, whether porous or impervious, should be noted as the work progresses.

In running drainage areas time may be saved by using the stadia hairs of the transit for measuring distances. If the transit has no stadia hairs the "thirty-four and a half minute method" may be employed. This depends upon the fact that the natural sine or tangent of 34½ minutes equals 0.01, very nearly, and consequently this angle subtends a distance at right angles to the line of sight of 1 foot at 100 feet, 2 feet at 200 feet, etc. The rodman having selected a point on the divide, azimuth and bearing, or simply the bearing, of the line joining the rodman's position with the transit is read and recorded by the instrumentman, after which he sets off 34½ minutes on his horizontal plate and then motions the rodman into this new line. The rodman then measures the distance between the two points, at right angles to either line of sight, to hundredths of a foot, or closer if possible, and this offset distance, multiplied by 100, gives the distance his first point is distant, in feet, from the instrument.

Many run-off formulas have been devised, but no one formula will apply in all cases. The *rate and duration* of the heaviest downpours are rarely known with any degree of precision, and frequently the character of the surface is uncertain. These, together with the area and slope, are factors affecting results. As a consequence, the run-off computed by the formula which best fits existing conditions can, at best, serve only as a guide to aid the engineer's judgment in deciding upon the proper area of water way to allow.

Generally it is better to leave an excess of waterway, rather than a deficiency, especially for small drains and culverts, but excessive rainfall at long periods may make this impracticable at a reasonable cost. An occasional washout on lines of average traffic is often preferable to the excessive first cost which would have to be incurred to prevent it.

**273. Formulas for the Area of Waterway to be Allowed** are numerous, but all contain some empirical constant, and therefore no one is applicable to all conditions of rainfall, slope, character of ground surface, etc., unless the constant, or constants, be definitely known for each particular case. Two of the simplest run-off formulas are given below:

(1) Myer's formula,

$$\text{Area of waterway in sq. ft.} = C\sqrt{\text{drainage area in acres}}. \qquad (377)$$

(2) Talbot's Formula,

$$\text{Area of waterway in sq. ft.} = C\sqrt[4]{(\text{drainage area in acres})^3}. \qquad (378)$$

In Myer's formula the coefficient $C$ may vary from 1 for flat country to 4 for rocky, mountainous country. For small drainage areas in most localities this formula tends to give excessive areas.

In Professor Talbot's formula $C$ is taken as $\frac{1}{5}$ or $\frac{1}{6}$, or even less, when the length of the valley is long in proportion to its breadth in districts not affected by accumulated snow. For rolling agricultural country where the valley is three or four times as long as it is broad, and where melting snow may cause floods, $C$ is taken as about $\frac{1}{3}$. For steep and rocky ground $C$ varies from $\frac{2}{3}$ to 1.

As an example, suppose it is desired to provide an opening to carry the drainage from 400 acres. The area, $A$, by Myer's formula, will be $C \times 20$, and by Talbot's, $C \times 89.44$. For the minimum values of $C$ given above, these formulas would then call for 20 and 14.9 square feet respectively, while for the maximum values they would call for 80 and 89.44 square feet respectively. Evidently there is room for wide variation in judgment in assigning the value of $C$ to be used. Good judgment, an intimate knowledge of local conditions and careful observation of flood discharge, as found from measurements at high water, or from the behavior of other openings in the vicinity under high-water conditions, must be the engineer's final guide. The writer has in mind two railway systems which built lines through the same section of country, one of which used a formula giving twice the area given by the formula used by the other.

Excessive rainfalls, such as occurred in the valley of the Brazos River in Texas in 1899, when the precipitation exceeded 30 inches in sixty hours, can not ordinarily be economically provided for. Nor can such rainfalls as occurred at Austin, Texas, in 1915, when 10 inches fell in twelve hours. One locality in southwest Texas reported 20.60 inches of rainfall in twenty-four hours during the year 1913. Adequate provision for such downpours is manifestly out of the question.

### 274. Given the Elevation of Center Line of Roadbed, the Elevation of Top of Paving of a Culvert beneath Center of Roadway, and the Grade or Grades of Culvert Paving, to Locate the Intersections of Side Slopes and Paving Grade Line.

FIRST CASE.—*Grade-line of culvert-bottom uniform.*

In Fig. 131 let the culvert-bottom have a uniform slope $S$ from end to end. Let the embankment side slopes be $s$, and the center fill $CK=h$. Let the half width of crown be $b$.

For the upstream end of culvert the two slopes meet at $D$. The fill at $J$ vertically beneath the edge of slope $B$ is $h'=h-b\tan i=h-bS$. From the triangles $BDH$ and $JDH$, $h'=HD\tan a+HD\tan i$, from which

$$HD=\frac{h'}{\tan a+\tan i}=\frac{h-bS}{s+S},$$

and $$\therefore \text{ distance of } D \text{ from center}=b+\frac{h-bS}{s+S}. \quad . \quad . \quad (379)$$

On the downstream side the distance out is found in like manner to be

$$d.o.=b+\frac{h+bS}{s-S}. \quad . \quad . \quad . \quad . \quad . \quad (380)$$

SECOND CASE.—*Grade-line of culvert-paving broken.*

In Fig. 131 let the grade-line from the inlet $D$ be uniform to some point $L$, distant $d$ from center. The distance out to $D$ is found as before, but from the geometry of the figure, the distance out to $M$ is given by the formula $d.o.=KL+LM$ $=d+\frac{QL}{s-S'}$. But $QL=h+RL-PQ=h+dS-(d-b)s$.

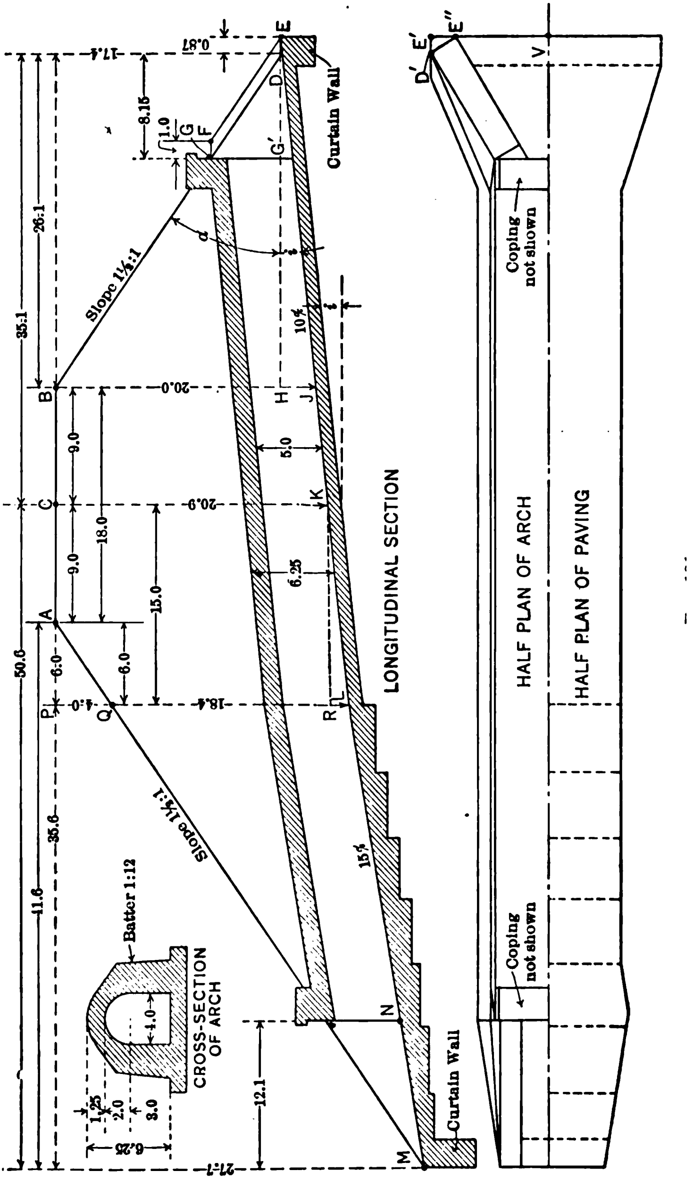
$$\therefore\ d.o.=d+\frac{h+dS-(d-b)s.}{s-S'}. \quad . \quad . \quad . \quad (381)$$

The distances out to faces of end walls will depend upon the height of culvert and thickness of crown of arch. Call the total height from flow line to top of crown of arch $h''$; the distance to be subtracted from above distances out will then be $\frac{h''}{s+S}$ on upstream side and $\frac{h''}{s-S}$ on downstream side.

The above treatment has been inserted at the suggestion of Mr. C. M. Kurtz, who supplied the following

EXAMPLE.—For the dimensions shown in Fig. 131, the following values are obtained:

By (379), $HE=9+\frac{20.9-9\times0.1}{\frac{2}{3}+\frac{1}{10}}=35.1$ feet.


LONGITUDINAL SECTION
HALF PLAN OF ARCH
HALF PLAN OF PAVING
CROSS-SECTION OF ARCH
Curtain Wall
Curtain Wall
Coping not shown
Coping not shown
Slope 1½:1
Slope 1½:1
Batter 1:12
E
D
G
F
G'
H
J
K
L
R
N
M
A
B
C
P
Q
E'
E''
D'
V
α
35.1
26.1
17.4
0.87
8.15
1.0
20.0
9.0
9.0
18.0
20.9
15.0
6.0
6.0
4.0
18.4
50.6
41.6
35.6
12.1
21.1
5.0
6.25
10⅘
15⅘
4.0
1.25
2.0
3.0
6.25

By (381), for the downstream side the

$$d.o.\text{ of } M = 15 + \frac{20.9 + 15 \times 0.1 - 6 \times \frac{2}{3}}{\frac{2}{3} - \frac{15}{100}} = 50.6 \text{ feet.}$$

The horizontal distance from upstream toe of slope $D$ to face of end wall is $\frac{6.25}{\frac{2}{3}+\frac{1}{10}} = 8.15$ feet; which locates the face of the end wall at a distance of $35.1 - 8.15 = 26.95$ feet out from the center. The face of downstream end wall is $\frac{6.25}{\frac{2}{3}-\frac{15}{100}} = 12.1$ feet in from $M$, or $50.6 - 12.1 = 38.5$ feet out from center of embankment.

The top width of wing wall is 2 feet, and the angle this makes with the axis of the culvert is 30 degrees. Therefore, $DE = D'E'$ (in plan) $= D'E'' \sin 30° = 1.0$ foot, and the distance out from center of curtain wall face is $35.1 + 1.0 = 36.1$ feet. The distance $VE'$ in the plan equals $2.0 + 9.15 \tan 30° + 2.0 \cos 30° = 9.01$ feet.

**275. Staking Out Openings for Trestle Bridges, etc.**—Where culverts, trestles, or other bridges are later to be constructed, openings across, or through, the embankments must be left. If the opening is for a culvert or drain which is later to be covered over, the same slope from top of bank (*T.B.*) to foot or toe of slope (*F.S.*) as for side slopes should be allowed, or at least a slope which makes an angle with the horizontal equal to the angle of repose. The planes of the side slopes will then intersect the inclined plane of the axial slope in straight lines. On irregular ground the intersection of these planes with the ground surface will not yield horizontal straight lines, and stakes must be set to mark points on the actual line of intersection. The plus stations at which these stakes are set must be recorded as well as the height to grade-line, or "fill," and their distances out from the center.

The volume of earthwork between top of bank and foot of slope will consist of one wedge and two pyramids and should, for precision, be computed by the prismoidal formula.

At the ends of trestle bridges it is better to set the foot of slope stakes so as to substitute two quarter-cones for the two pyramids, as this is approximately the form into which the pyramids will finally weather. Every element of the quarter cones will have the same slope, which, for earth fills, is usually taken as 1½ to 1. A sufficient number of stakes must be set to mark the outline of the intersection of the conical surface with that of the ground. The plus station and distance out from the center for each stake must be measured and recorded for the purpose of computing the conical volumes.

At the top of bank a pile bent is driven and capped to support the ends of the trestle stringers. Frequently heavy planking, 3 or 4 inches thick, is spiked or bolted to the posts of the bent on the embankment side to form a bulkhead to take the thrust of the earth. In such a case a part or all of the wedge and quarter cones (or pyramids) will be eliminated according as the bulkhead cuts off part or all of them. If only a part is cut off, sufficient measurements must be taken to make it possible to compute the actual quantity of earthwork placed.

**276. A Pile Bent** consists, generally, of four, five, or six piles driven in a vertical plane at right angles to the axis of the road, and then cut off at a predetermined height and capped with a heavy timber, usually 12×12 inches in cross-section, though two 4×12-inch timbers let into opposite sides of the top of pile are sometimes substituted. Stringers, consisting of at least two heavy timbers, are set upon the caps nearly under, but a little outside of the axis of each rail. Solid caps are usually held in position on the piles by *drift bolts* 1 inch or more in diameter and 2 feet or more in length, which are driven into holes, slightly smaller than the bolts, which holes are bored through the caps and into the stringers. Sometimes the tops of piles or posts are cut to form tenons which fit into mortises cut into the solid caps. Again, the caps may consist of two timbers, one on each side, which rest on shoulders or notches cut at the tops of the piles, and having bolts passed through both cap and piles to bind them all together.

The outside piles are usually driven with a *batter* varying from 1 to 12 to about 1 to 4. Tall bents have the piles connected by diagonal *sway bracing*, bolted to them, in order to prevent lateral oscillation. Very tall bents require longitudinal bracing also.

**277. Cut-offs for Piles** must be so given by the Engineer that when the piles have been capped and the stringers and overlying cross-ties placed in position later on, the rails will come to the proper grade-line. The cut-off marks consist usually of nails or tacks driven into the piles at a definite distance below the points at which the piles are to be sawed off. This distance should contain no fractions of a foot, and when possible should be the same for all the bents of each bridge. In any event a foreman of the bridge gang must be supplied with a memorandum of the cut-off heights.

For trestles located on anything but a level grade the rise or fall between successive bents must be carefully figured, and when the trestle is on a curve (which is very undesirable) the super-elevation of outer rail must be provided for by making the cut-offs higher by the proper amounts on the outside, and lower on the inside of center line, unless the specifications call for the inner rail instead of the center line to be laid to grade. Trestles on curves are to be avoided whenever possible.

Payments for piling may be based upon the number of lineal feet below caps only, or by one price for such portion and a smaller price for the portions cut off. In either case a *Pile Recorder* must be constantly on the ground, not only to record the lengths of each pile driven, but also to see that all are driven in accordance with the specifications.

Pile trestles are limited in height by the lengths of suitable piles available and by the depths to which they must be driven in order to secure adequate bearing. Taller trestles must be built of framed bents.

**278. Staking Out Foundations.**—For trestle bridges a stake must be driven at the point where each pile is to be driven into the ground at each bent. For culverts the limits of the foundation excavation must be set out by stakes at all outside angles. The plans for these are usually worked out in the office and blue prints furnished the construction engineer and the foreman of the gang which is to build the culvert. It is desirable to have the axes of all culverts, trestle bents, bridge piers, etc., at right angles to the axis of the road, but frequently this is not possible, and the structure must be built on a *skew*. The angle of skew must be determined from conditions on the ground before the plans are drawn.

In locating foundations, horizontal angles should be set off with a transit, and linear measurements should be made with a steel tape which has previously been compared with a standard.

**279. The Piers and Abutments** for truss bridges must be very accurately located, the spacing being done with a steel tape whose constants are known, and the center and limits being marked by stakes. On tangents the centers are easily located and referenced, but on curves this is not so easy, as the center of track cannot be taken as the center of pier on account of the clearance necessary for trains.

Bridges on curves should be avoided whenever possible, but when they cannot be avoided the centers of piers are to be placed at the intersection of pier-axis and "bridge-chord."

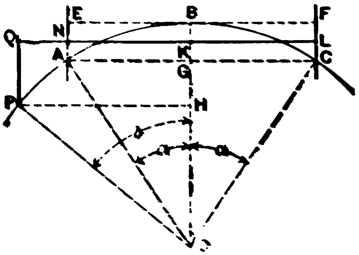


Fig. 132.

In Fig. 132 *ABC* is the center line of track, *AE* and *CF* the pier-axes. At the mid-point of the arc *AC* the tangent *EF*, parallel to *AC*, is drawn; make *AN* = *NE* = *CL* = *LF*, and draw *NL*, which is the bridge-chord. The points *N* and *L* are the centers of the piers.

Should *L* or *N* be inaccessible, they may be located from a point *P* on some accessible portion of the curve. To do this take *PH* perpendicular to [illegible] and find that

$$[illegible] \qquad (382)$$

then will

$$[illegible] \qquad (383)$$

The manner of building the piers determines [illegible] the nature of the [illegible] the bridge [illegible] jointly within the [illegible] of the bridge engineer and require [illegible] much space [illegible] preliminary estimates it will often be sufficient [illegible] to make [illegible] soundings with gas-pipe in order to determine the depth to a suitable foundation and the nature of the overlying deposits, the core forced up within the pipe serving for the latter purpose.

**280. Relation of Trestles to Embankments.**—Low embankments involve less first cost and smaller maintenance charges than low trestles. High embankments cost more to build but less for upkeep than high trestles. There is some intermediate height at which the two first costs are equal, but this height in each particular case will depend upon market prices, labor, transportation, and a number of local conditions. As a rough average 25 feet may be taken. This means that for heights less than 25 feet embankments should be built, while for greater heights trestles are to be erected. Taking maintenance charges into account also the limiting height may be 40 feet or more. If materials for embankments are scarce or difficult to move the limiting height may be less, but if an abundance of material is available for embankments while trestle materials are scarce or high-priced, the limiting heights may be greater. Trestles carry the hazard of fire in addition to maintenance charges. The cost of embankments increases much more rapidly than the height, while for trestles the increase in cost is less rapid than the height.

There is another limiting height, somewhat variable because of local conditions and market prices, above which steel viaducts or bridges should take the place of wooden trestles. As a rough average 50 feet may be taken as this limit.

**281. Filling in Trestles.**—During the earlier stages of railroad building trestles were much more freely used than is the practice now. Many roads have filled in trestles of moderate height, either leaving the old timbers to decay or removing them in cases where the value of the timber salvaged exceeds the cost of withdrawal. Sometimes light, temporary trestles are built and the embankment constructed from these by the use of dump cars which are loaded by means of a steam shovel at some point on the road which does not involve excessive train haul. A comparatively small culvert may often be substituted for a long, expensive trestle. In no case, however, should the area of waterway be so greatly reduced as to endanger the roadbed or to hold back flood waters to such an extent as to invite damage claims and suits by property owners above.

Court awards for damages, especially where juries fix the amounts, are more easily obtained against corporations than against individuals, sometimes requiring scarcely the shadow of a proof.

**282. Tunnels** are employed instead of open cuts where open excavation involves excessive cost, or to avoid steep grades, undue rise and fall, very high summits or too great length of line. They are objectionable in that they increase the time required for construction and also the cost. They are lacking in natural ventilation and light. Wherever possible they should be constructed on a tangent throughout, but not infrequently this is impossible and curves must be introduced. Usually these curves are at the tunnel ends.

The alignment of a tunnel is based upon carefully made precise surface surveys. A permanent station in the vertical plane of the tunnel axis, or at two or more such points if there is more than one summit in the divide through which the tunnel is driven, are established, and from this (or these) other points are set, in the vertical plane in which the axis of the tunnel tangent lies, beyond the ends of the tunnel, to serve as permanent backsights for use during construction. Triangulation may have to be resorted to in locating permanent points of reference, such as those mentioned above, and enough of these should be set to quickly locate the tunnel axis at any point from which construction may be carried on.

The angular measurements should be made with a precise transit in the best possible adjustment, and many repetitions and reversals should be made in order to eliminate all appreciable errors. A striding level on the horizontal axis of the telescope is desirable as aiding in keeping the plane of sight vertical when marking points on stations which are higher or lower than the instrument.

Linear measurements should be made with a standardized steel tape, and corrections made for temperature, pull, slope, sag, etc. Plumb lines should be used for sighting instead of rods, though a rod made of a 1×3½-inch, steel-shod strip of wood which has a straight, sharp line marked on it from end to end of the flat side may be used. An attached rod-level enables the rodman to hold the rod in a vertical position if the rod-level is set truly at right angles to the line on the face of the rod. The best work can be done on cloudy days or in the early mornings, or sometimes at night, in which latter case plummet lamps should be used or the plumb line should be illuminated. Inside the tunnel plummet lamps are suspended from plugs let into the roof, or from hooks driven into the timbering.

Particular care must be exercised in giving points on curves in tunnels, in order to secure precise alignment of the tunnel tangent, for the work usually proceeds from both ends and a fit must be made where the headings meet. Every possible check on angles and distances should be taken. Center stakes should not set more than 50 feet apart, and preferably less. Short tangents whose intersection lies within the tunnel should be run to the *P.I.* and their lengths measured. Also the long chord, mid-ordinate, and external as checks. Too many check measurements can not be had.

To keep tunnels free from ground- or seep-water, longitudinal drainage must be provided. This may be either by means of open conduits or covered pipes. Since construction proceeds from both ends, there must either be a summit within a tunnel or the ground-water must be kept down by means of pumps. The least allowable slope for drainage should be not less than 0.1 foot in 100 feet.

**283. Tunnel Cross-sections** vary greatly in different tunnels and may even vary in different portions of the same tunnel in cases where the material penetrated varies in character. If this material is solid rock no lining may be needed and the sides may be vertical, the bottom nearly flat, and the top an oval. In soft material the cross-section may have to be vertical or nearly so, and top, bottom, and sides lined with masonry. For single track tunnels on tangent the clear width should be 15, and preferably 16, feet, and the top is generally finished with a semi-circular arch. On curves the tunnel width must be increased and the track set off center so as to give the same clearance as on tangents. For double track tunnels the clear width should be 15 (and preferably 16) feet, feet, plus the distance between track centers. The clear height above top of tie for double- as well as single-track tunnels should be 22.5 feet. The arch for double-track tunnels is generally a three-centered oval, the radii depending upon the distance between centers of tracks. If they are to be lined, tunnels require the removal of additional material to make room for the lining, which is now generally of concrete, but which may be of hard-burned brick.

Measurements from which to determine the quantity of material removed are best made radially from a line in the vertical plane of the axis at a uniform distance above the grade-line. The angles which the radial measuring lines make with the vertical are determined by some species of protractor, and distances out along the radial lines by means of a sliding rod attached to the protractor. By plotting these measurements to scale on cross-section paper the area at each station, and sub-station, can be found by means of a planimeter, or by counting the number of squares included within the irregular curve which forms the perimeter. Cross-sections should be taken at short intervals, say 20 or 25 feet along the axis. More care is necessary in determining the volume in tunnels than is the case for ordinary earthwork, because the unit cost of moving such material is much greater in the case of tunnels.

Sometimes, though rarely, the tunnel lining is made of timber where this is inexpensive. Either concrete or high-grade brick masonry is generally used, the top being in the form of an arch. In crowded cities, where the head room is limited, the roof may be flat, being supported by steel beams.

**284. Shafts** are frequently used to facilitate construction by offering two additional working faces for each shaft, for the headings are driven both ways from the bottom. The form most frequently used is rectangular, with the longer side parallel to the tunnel axis. For aligning the headings points are carefully located in the vertical plane of the tunnel axis, one at each side of the shaft, and these points are transferred to the bottom of the shaft by lines having heavy plumb bobs, swung in water, at their lower ends. From a carefully determined elevation at the surface, steel-tape measurements fix the proper grade of the bottom of the shaft.

**285. Ventilation of Tunnels** is generally secured by the passage of trains, though artificial methods may be employed. Shafts used during construction have been tried as ventilators afterwards, but with small success. They are most generally closed after having served their purpose during construction. Artificial ventilation is necessary while construction work is in progress, especially if much blasting is necessary. Drills operated by compressed air serve the double purpose of operating the drills and supplying fresh air. The expansion of the liberated air has also a cooling effect.

**286. Tunnel Portals.**—There is generally more or less open cutting at tunnel ends, and as the overlying material at entrance and exit has little or no self-supporting power, because of limited thickness, special treatment is necessary, both to prevent overlying material from slipping into the cuts, and for the sake of appearances. From the arch and side walls a face wall is built out to the sides of the cut and this wall is carried up a short distance above the outside of the arch crown. This wall may be backed by layers of loose stones, carefully laid without mortar, and it should have a batter of not less than 1 inch per foot, and preferably 2 inches per foot.

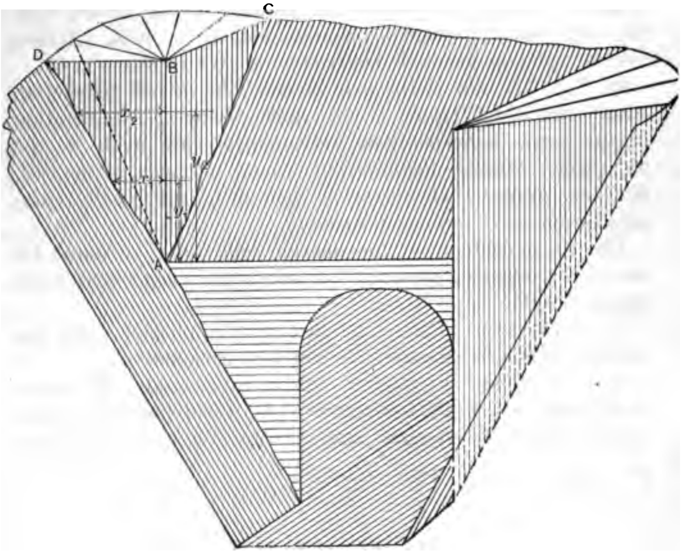


FIG. 133.

Above the face wall the inclined surface of the material overlying the tunnel, and the planes of the side slopes of cut should be joined by a cone-shaped surface having its axis vertical. If the face of the excavation can be made vertical, the quarter cone will be as shown on the left of the entrance in Fig. 133. If battered, it will be as shown on the right. Owing to the irregular lines along which rock usually breaks this surface will not be truly conical. The field measurements on these "quarter cones" (of which there are two to each portal) are referred to the vertex of the cone as origin and its axis as the axis of $y$; lines measured at right angles to the $y$-axis out to the actual surface constitute values of $x$, while the plane in which any particular set of $x$'s lie is referred to a plane through the $y$-axis and parallel to the tunnel axis, the angle between them being measured in the field. A convenient value of the angle between successive $xy$ planes is 15°.

In Fig. 133, $AB$ is the axis of cone, $BC$ a line parallel to tunnel axis, and $BD$ a line at right angles thereto. The notation of the figure indicates how measurements are made in the 90° plane. Similar measurements would be made in the 75°, 60°, etc., planes. The areas in each plane are readily computed from the $x$ and $y$ coordinates.

The cubic contents of the quarter cones may be found by one of the following methods,* of which the second gives more precise results:

First Method.—*By Average Sections.* Applicable where the several sections as measured are not very irregular.

Let $V=$ volume of quarter cone in cubic yards; $R=$radius of the cone which will be generated by revolving the average section about the vertical axis; $A=$area of average section; $H=$height of cone. Then, since $R=\frac{2A}{H}$,

$$V=\frac{1}{27}\times\frac{H}{3}\times\frac{\pi R^2}{4}=\frac{A^2}{25.783H}=0.0388\frac{A^2}{H}. \quad . \quad . \quad (384)$$

To find the area of the average section $A$ add together the half areas of the 90° and 0° sections, and the full areas of intermediate sections, and divide this sum by one less than the number of sections.

Example.—Let the dihedral angle between sections be 15° and let the areas of successive sections, beginning with the

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* Treatment and example furnished by Mr. C. M. Kurtz.

90° section and ending with the 0° section, be as given in the equation below, the area of the average section will be,

$$A=\frac{\frac{1}{2}\times 204.34+340.48+402.17+462.13+419.41+476.00+\frac{1}{2}\times 594.70}{6}$$
$$=416.628 \text{ square feet.}$$

For this case the height of the cone is 31.9 feet, and, therefore, by (384), $V=0.0388\frac{(416.628)^2}{31.9}=211.1$ cubic yards.

SECOND METHOD.—*By Centers of Gravity of Sections.*

Let $V$ = volume between two adjacent sections and let there be $n$ such volumes in each quarter cone. The dihedral angle between sections will therefore be $\frac{90°}{n}$. Let $A_1$ and $A_2$ be the areas of two successive sections. Let $R_1$ and $R_2$ be the radii of arcs described by the centers of gravity when the sections are rotated about the axis of the cone through the angle between successive sections. Then the volume between the two sections will be, by taking the mean of the areas and the mean of the radii and applying Guldin's rule, that the volume generated by a moving area equals that area multiplied by the length of the path through which its center of gravity is moved, and remembering that 1° equals $\frac{\pi}{180}$ in circular measure, as below:

$$V=\frac{90°}{n}\times\frac{\pi}{180}\times\left(\frac{R_1+R_2}{2}\right)\left(\frac{A_1+A_2}{2}\right)=\frac{\pi}{8n}(R_1+R_2)(A_1+A_2) \text{ cu. ft.}$$

If $n=6$, or the angle between successive sections is 15°, the above formula reduces to

$$V=\frac{3.1416}{48}(R_1+R_2)(A_1+A_2) \text{ cu. ft.}=\frac{3.1416}{48\times 27}(R_1+R_2)(A_1+A_2)$$
$$=0.002424(R_1+R_2)(A_1+A_2) \text{ cu. yds.} \quad . \quad . \quad . \quad (385)$$

The centers of gravity of sections may be found by dividing the sections into triangles and trapezoids, or each trapezoid may be subdivided into a rectangle and a triangle, and then taking moments about the vertical axis of the quarter cone. The sum of the moments divided by the sum of the areas will give the radius of the section.

EXAMPLE.—For a certain quarter cone the sum of the small areas for the section at 90° is 427.23 and the sum of the moments is 3849.46, and the corresponding quantities for the section at 75° are 383.26 and 3544.04 respectively. Then will $R_1 = \frac{3849.46}{427.23} = 9.01$, and $R_2 = \frac{3544.04}{383.26} = 9.247$. Therefore $R_1 + R_2 = 18.257$ and $A_1 + A_2 = 810.49$, which in (385) gives

$$V = 0.002424 \times 18.257 \times 810.49 = 35.86 \text{ cubic yards.}$$

$R_1$ and $R_2$ might have been found approximately by plotting the sections on cardboard of uniform thickness and weight, then cutting out the resulting irregular figure and balancing on a knife-edge parallel to the axis of the quarter cone, or by suspending from two different points and drawing lines along the extensions of the suspending lines, the intersection of these lines marking the center of gravity. The determination by moments is preferable.

## ARTICLE 23. FINISHING EARTHWORK. TRACK LAYING.

**287. Center Stakes** are set after excavations and embankments have been brought approximately to the levels called for by the cross-section stakes. New hubs are set in the same vertical lines as the original hubs which were placed during location, these verticals being recovered by finding the intersections of the vertical planes through two or more sets of reference points. To do this the transit is set up over one of the hubs in one of the reference lines and the transit oriented by sighting another reference point of this set. This line is prolonged and two temporary hubs set a few feet apart, with the axis of the road between them. The transit is then moved to a hub on another of the reference lines and the process repeated. The intersection of two cords stretched between the tacks of the pairs of temporary reference hubs fixes the location of the center line hub, which should be permanently set. To avoid setting the second set of temporary hubs the transit rod may be moved along a cord stretched between the tacks of the first pair until it is cut by the line of sight when the transit is in its second position. A permanent hub is established at this intersection.

With the transit set over one of the recovered center line hubs, a pointing is made to the next one and intermediate center stakes are set opposite the stations cross-sectioned. On curves the center line is re-run just as in location, except that the stakes may be set closer together, say 50 or 25 feet apart. All distances should be carefully rechained.

On long tangents it may happen that intermediate hubs do not all lie in the same vertical plane as the line joining the terminal hubs, so that, if the hubs were joined with each other in succession the resulting line would contain one or more "swings." If these swings are small and tend to balance each other, it may be possible to adjust the final line so as to join the terminal hubs with a straight line on which the finishing work is done. If a swing is large it should be carried forward to the nearest summit and a small angle introduced there. This in order to eliminate the unsightly appearance resulting from badly aligned track. If placed at the bottom of two adjacent grades, the swing will still be apparent to one riding on the rear platform of a train. Minor errors of location on curves may be corrected by slightly changing the degree of curve as run for finishing purposes, or when giving track centers. Swings on tangents may be hidden at summits when setting track centers if this has not previously been done.

To insure full width of finished roadbed, stakes should be set at the half-width of roadbed out from the center stakes on lines at right angles to the center line of roadbed.

**288. Grade Stakes** are set beside the center stakes, the tops of the grade stakes being brought to the proper elevation for the finished roadbed. In fills allowance should be made for shrinkage unless the specifications provide for its omission. There is a difference of practice in this respect. Some specifications require the grade stakes to cover this allowance by having the proper amount added to the profile grade heights in embankments, with the finished top at the full width of roadbed. Others require no allowance to be covered by the grade stakes, the gradual shrinkage being cared for by periodical additions of earth or ballast brought in by train. In this case the width of crown required when finishing is done must be increased as the height of embankment increases.

EXAMPLE.—Suppose a 20-foot fill to be required at a certain station where the material is expected to shrink 8% vertically. The first method would require the top of grade stake to be set 1.6 feet higher than the established sub-grade, or 21.6 feet above the original ground-surface. If the final crown width is to be 18 feet, the grade stakes at sides of embankment would be set 9 feet out each way from center. The second method would require the top of stake to be driven to sub-grade, or 20 feet above the original ground-surface, but the side grade stakes would, however, be set at a distance out of 9.0+1.6×1.5 =11.4 feet out on each side, supposing the final side slopes to be 1½ to 1.

On tangents grade stakes at the center only will generally suffice, but on curves they should be set beside the top side stakes also, or the side stakes should be driven until their tops are brought to the required elevation. This is to insure the plane of the roadbed having the slope necessary to secure the proper super-elevation of outer rail. Section **228** explains the method of finding the plus or minus addition to the elevation of top of center grade stake.

A second set of grades are run as a check after the earthwork has been brought to the tops of the grade stakes set in the manner described above, lest any of these stakes should have been disturbed.. Both top and side slopes must be brought to smooth, neat plane surfaces before the work is ready for acceptance. Sometimes unnecessary precision is required in the matter of finishing, entailing relatively heavy expense when the work is done with a shovel. A steel-bladed road-grader having the scraping blade set at right angles to the direction of travel gives satisfactory results for the top surface if manipulated by a skillful operator, who is directed by another man walking a short distance behind the grader. The side slopes are usually finished by hand, but a suitable drag, or special hand-guided scraper, drawn by mules, may be made to answer.

**289. Sodding.**—The side slopes, of embankments especially, should be sodded to prevent erosion, particularly while the fill is green. It will pay to also sod the side slopes in excavation, but usually this necessitates spreading a layer of rich surface soil on the face of the cut, whereas this is not so frequently required on embankments, especially if care is exercised in placing the material in embankments in such manner as to bring the original surface material to the sides as the filling progresses. In localities where the seasons are favorable, a suitable sod may be secured by planting the slopes with grass seed of such varieties as thrive in those particular localities.

Sometimes chunks of surface sod must be set at intervals well down in the slope surface so that the grass roots may take hold readily. Spreading takes place by means of runners sent out by the bunches of sod so planted. In the warmer portions of the United States, Bermuda grass forms an excellent tough sod if there is sufficient rainfall to make it grow thriftily. It is better to plant bunches of the sod 2 or 3 feet apart than to streak off furrows and strew the grass roots, from which the earth has been shaken, in them, as is so generally done on levee construction.

Unfortunately sodding is not generally done, because of the added cost of construction. The saving in maintenance will, however, generally offset the cost of planting many times over.

Because the angles formed by the intersection of two surfaces at top and bottom of earth side slopes soon weather into rounded forms, the obvious thing to do is to round these off during construction before sodding. This has not been done as generally as should be the case. At the upper sides of slopes the rounding takes place by erosion and at the lower sides by deposition. In cuts the removal of the material washed in by heavy rains is frequently an item of considerable expense. Sodding the side slopes will materially reduce this.

**290. Track Centers and Grade Stakes** must be given in advance of the actual laying of the track. The centers consist of nails or tacks driven into the tops of stout stakes, say 2×2 inches in cross-section, located every 100 or 200 feet apart on tangents and preferably only 50 feet apart on curves. The tops of the center stakes may be brought to the grade of the top of rail and so made to serve as finishing grade stakes, but it is better to set grade stakes at one side of track, the tops of these stakes to be at the elevation of top of rail. If the roadbed is not ballasted until after the rails have been laid on the sub-grade, grade stakes need not be given until just before the ballast is to be applied. It is better for the final alignment of the rails to have the ballasting done first, but it is cheaper to haul this in by train after the track has been laid, the ballast being worked in under the ties, which must be blocked up for the purpose.

If "swings" have not been hidden at summits when the finishing centers were given this must be done when the track centers are set.

Track laying usually costs from $500 to $600 per mile, depending largely upon the weight of steel used.

## ARTICLE 24. MONTHLY AND FINAL ESTIMATES.

**291. Monthly Estimates** are made by the engineers in charge of construction about the end of each month, and upon these the division engineer bases his estimate, which he forwards to the chief engineer for approval. The contractor receives his compensation some days later, usually about the 15th or 20th of the month following. Monthly estimates should always be based on actual measurements and never guessed at, particularly if several classifications are to be made. The total quantity of work done or material delivered is to be estimated, then the difference between any estimate and the last preceding one will be the estimate upon which the contractor receives his installments.

**292. For Earthwork**, measurements (when needed) are only approximate, but it is best to make them with level and tape even for monthly estimates. It will be sufficient to compute volumes by averaging end areas, no attention being paid to the prismoidal correction. Care must be taken, however, that such estimates are not in excess—in fact, it is well to keep slightly within the actual quantities on account of the greater cost and labor required to finish the work, which would make the latter part appear so much less profitable to the contractor as sometimes to induce a disposition to abandon the work before completion.

**293. The Classification of Earthwork.**—It is customary to group earthwork in excavation, according to the difficulty of removal, into three classes—earth-excavation, loose rock, and solid rock—though other classifications are frequently made.

*Earth-excavation* includes all earth, sand, loam, and loose stones that can be moved with the plow and scraper.

*Loose rock* includes all stones and detached boulders less than from 1 to 3 cubic yards in size, and all slate, shale, or cemented gravel requiring the use of the pick and bar, but which may be removed without blasting.

*Solid rock* includes all boulders above a certain size (usually from 1 to 3 cubic yards, as specified) and all rock masses that cannot be removed without blasting.

The relative prices vary, but a ratio of 1 : 3 : 7 will not be far from an average for the more common conditions arising in railroad work.

The necessity for a correct classification is evident, and the engineer should keep full notes, and make careful measurements whenever a given volume involves more than one class of earthwork. It is customary to specify that his decision is final, and therefore his measurements should be carefully made during the progress of the work, and notes on the nature of material taken at the same time.

A note-book should be kept showing the measurements and amounts of each class of material for each station, together with the date of completion and acceptance.

**294. A Progress Profile** should accompany the monthly estimate to exhibit graphically the amount of work done during the month, different colors being used for the different months. The final profile should show approximately the progress of the work. The colors may be laid on with a brush, or hatchings made with a pen; in neither case should the color obscure the lines of the profile-paper. A duplicate progress profile should be retained in the resident engineer's office; if transparent profile-paper is employed, one may be simply traced through from the other. A further advantage of the transparent paper is that blue-prints of any portion of the profile may be readily made when duplicates are desired, provided the drawings are in black or any color admitting blue printing.

**295. Masonry** is to be measured in cubic yards, and any material on hand, but not in place, is to be measured and estimated. The classification of masonry must be according to specifications. Foundation-pits for piers or culverts must be measured as soon as completed, and before the masonry has been put in place.

**296. Bridges** must be estimated by measurement, or by checking up material in place and that on hand but not in-place.

For trestle bridges, or foundations requiring piling, the actual number of linear feet below cap must be measured; this necessitates the constant supervision of the engineer or an assistant, sometimes known as a "pile-recorder," whose duty it is to see that all piles come up to specifications and are driven in accordance therewith.

All framing-timber in place, or delivered but not in place, is to be included in the estimate, the amount being obtained by measurement.

Steel spans or trestles are to be estimated, in the same manner as wooden trestles, by checking up or measuring the material on hand and in place.

297. **Track Material** must be checked up either by the "material clerk" or the engineer in charge of track. Ballasting properly belongs with the graduation, but may be put in place after the rails have been laid; in either case it is estimated in accordance with the specifications.

For preliminary and monthly estimates it will be sufficient to estimate track material by means of tables showing the number of cross ties for a given spacing and the weight of steel for a given rail section, but before the final estimate is made all material must be measured or counted.

298. **Blank Estimate-sheets** are sent out from the chief engineer's office to be filled out by the engineers making estimate, who should retain a copy of each estimate rendered. On these sheets should appear the total quantity estimated, the amount of the last preceding estimate, and the estimate for the month, which will be the difference of the other two.

The resident engineer's estimate must show not only the quantity of material, but its value in dollars and cents computed from the contract price. The footings of the several columns then serve as a check upon each other.

299. **The Monthly Payments** are not made for the full amount estimated, but from 10 to 20 per cent is retained until after the final estimate has been made, in order to insure the completion of the work by the contractor, and to be used as a fund from which to withhold the amount of damages provided in the contract for failure to comply with all its provisions.

**300. Extras** incident to minor changes, or to the protection or drainage of the work, are usually shown on the final estimate, but a better way would be to require the contractor to present his bill for extras at the end of each month, and to incorporate them in the monthly estimate when they are just. The engineer should take measurements upon any extra work at the time of its completion, and should keep a record thereof. If the extras are of a nature not admitting of measurement, he should note the compensation to be allowed at the time the extra work is done.

**301. The Final Estimate** must include all earthwork moved, all material in bridges, all masonry in foundations, culverts, piers, and tunnels, and all other material supplied or work done in compliance with the contract. The engineer should keep his notes full and complete during the construction of the work, in order to be able to meet the contractor's claims for extras or complaints as to classification. Any items that may have been overlooked in making up the monthly estimates must be included here.

**302. Acceptance.**—Until the engineer has pronounced the work satisfactory and formally accepted it the contractor is liable for its condition, and must make good all damage caused by accident or storm. The road-bed and track may be accepted without special test; but all spans should be subjected to a specified test-load, under which they must show not more than a certain maximum deflection, so their acceptance will come last.

Sometimes the contract requires a particular structure or class of structures to be maintained in good order for a certain length of time after completion, and a percentage is retained to cover the case.

After final acceptance the work is paid for in accordance with the final estimate.

# TABLES.

| Deg. | Radius. | Deg. | Radius. | Deg. | Radius. | Deg. | Radius. | Deg. | Radius. |
|---|---|---|---|---|---|---|---|---|---|
| 0° 0′ | Infinite | 1° 0′ | 5729.65 | 2° 0′ | 2864.93 | 3° 0′ | 1910.08 | 4° 0′ | 1432.69 |
| 1 | 343775. | 1 | 5635.72 | 1 | 2841.26 | 1 | 1899.53 | 1 | 1426.74 |
| 2 | 171887. | 2 | 5544.83 | 2 | 2817.97 | 2 | 1889.09 | 2 | 1420.85 |
| 3 | 114592. | 3 | 5456.82 | 3 | 2795.06 | 3 | 1878.77 | 3 | 1415.01 |
| 4 | 85943.7 | 4 | 5371.56 | 4 | 2772.53 | 4 | 1868.56 | 4 | 1409.21 |
| 5 | 68754.9 | 5 | 5288.92 | 5 | 2750.35 | 5 | 1858.47 | 5 | 1403.46 |
| 6 | 57295.8 | 6 | 5208.79 | 6 | 2728 52 | 6 | 1848.48 | 6 | 1397.76 |
| 7 | 49110.7 | 7 | 5131.05 | 7 | 2707.04 | 7 | 1838.59 | 7 | 1392.10 |
| 8 | 42971.8 | 8 | 5055.59 | 8 | 2685.89 | 8 | 1828.82 | 8 | 1386.49 |
| 9 | 38197.2 | 9 | 4982.33 | 9 | 2665.08 | 9 | 1819.14 | 9 | 1380.92 |
| 10 | 34377.5 | 10 | 4911.15 | 10 | 2644.58 | 10 | 1809.57 | 10 | 1375.40 |
| 11 | 31252.3 | 11 | 4841.98 | 11 | 2624.39 | 11 | 1800.10 | 11 | 1369.92 |
| 12 | 28647.8 | 12 | 4774.74 | 12 | 2604.51 | 12 | 1790.73 | 12 | 1364.49 |
| 13 | 26444.2 | 13 | 4709.33 | 13 | 2584.93 | 13 | 1781.45 | 13 | 1359.10 |
| 14 | 24555.4 | 14 | 4645.69 | 14 | 2565 65 | 14 | 1772 27 | 14 | 1353.75 |
| 15 | 22918.3 | 15 | 4583.75 | 15 | 2546.64 | 15 | 1763.18 | 15 | 1348.45 |
| 16 | 21485.9 | 16 | 4523.44 | 16 | 2527.92 | 16 | 1754.19 | 16 | 1343.15 |
| 17 | 20222.1 | 17 | 4464.70 | 17 | 2509.47 | 17 | 1745.26 | 17 | 1337.65 |
| 18 | 19098.6 | 18 | 4407.46 | 18 | 2491.29 | 18 | 1736.48 | 18 | 1332.77 |
| 19 | 18093.4 | 19 | 4351.67 | 19 | 2473.37 | 19 | 1727.75 | 19 | 1327.63 |
| 20 | 17188.8 | 20 | 4297.28 | 20 | 2455.70 | 20 | 1719.12 | 20 | 1322.53 |
| 21 | 16370.2 | 21 | 4244.23 | 21 | 2438.29 | 21 | 1710 56 | 21 | 1317.46 |
| 22 | 15626.1 | 22 | 4192.47 | 22 | 2421.12 | 22 | 1702.10 | 22 | 1312.43 |
| 23 | 14946.7 | 23 | 4141.96 | 23 | 2404.19 | 23 | 1693.72 | 23 | 1307.45 |
| 24 | 14323.6 | 24 | 4092.66 | 24 | 2387.50 | 24 | 1685.42 | 24 | 1302.50 |
| 25 | 13751.0 | 25 | 4044 51 | 25 | 2371.04 | 25 | 1677.20 | 25 | 1297.58 |
| 26 | 13222.1 | 26 | 3997.49 | 26 | 2354.80 | 26 | 1669.06 | 26 | 1292.71 |
| 27 | 12732.4 | 27 | 3951.54 | 27 | 2338.78 | 27 | 1661.00 | 27 | 1287.87 |
| 28 | 12277.7 | 28 | 3906.54 | 28 | 2322.98 | 28 | 1653.01 | 28 | 1288.07 |
| 29 | 11851.3 | 29 | 3862.74 | 29 | 2307.39 | 29 | 1645.11 | 29 | 1278.30 |
| 30 | 11459.2 | 30 | 3819.83 | 30 | 2292.01 | 30 | 1637.28 | 30 | 1273.57 |
| 31 | 11089 6 | 31 | 3777.85 | 31 | 2276.84 | 31 | 1629.52 | 31 | 1268.87 |
| 32 | 10743 0 | 32 | 3736.79 | 32 | 2261.86 | 32 | 1621.84 | 32 | 1264.21 |
| 33 | 10417.5 | 33 | 3696 61 | 33 | 2247.08 | 33 | 1614.22 | 33 | 1259.58 |
| 34 | 10111.1 | 34 | 3657.29 | 34 | 2232.49 | 34 | 1606.68 | 34 | 1254.98 |
| 35 | 9822.18 | 35 | 3618.80 | 35 | 2218.09 | 35 | 1599.21 | 35 | 1250.42 |
| 36 | 9549.34 | 36 | 3581.10 | 36 | 2203.87 | 36 | 1591.81 | 36 | 1245.89 |
| 37 | 9291.29 | 37 | 3544.19 | 37 | 2189.84 | 37 | 1584.48 | 37 | 1241.40 |
| 38 | 9046.75 | 38 | 3508.02 | 38 | 2175.98 | 38 | 1577.21 | 38 | 1236.94 |
| 39 | 8814.78 | 39 | 3472.59 | 39 | 2162.30 | 39 | 1570.01 | 39 | 1232.51 |
| 40 | 8594.42 | 40 | 3437.87 | 40 | 2148.79 | 40 | 1562.88 | 40 | 1228.11 |
| 41 | 8384.80 | 41 | 3403.83 | 41 | 2135.44 | 41 | 1555.81 | 41 | 1223.74 |
| 42 | 8185.16 | 42 | 3370.46 | 42 | 2122.26 | 42 | 1548.80 | 42 | 1219.40 |
| 43 | 7994.81 | 43 | 3337.74 | 43 | 2109.24 | 43 | 1541.86 | 43 | 1215.30 |
| 44 | 7813.11 | 44 | 3305.65 | 44 | 2096.39 | 44 | 1534.98 | 44 | 1210.82 |
| 45 | 7639.49 | 45 | 3274.17 | 45 | 2083.68 | 45 | 1528.16 | 45 | 1206.57 |
| 46 | 7473.42 | 46 | 3243.29 | 46 | 2071.13 | 46 | 1521.40 | 46 | 1202.36 |
| 47 | 7314.41 | 47 | 3212.98 | 47 | 2058.73 | 47 | 1514.70 | 47 | 1198.17 |
| 48 | 7162.03 | 48 | 3183.23 | 48 | 2046.48 | 48 | 1508.06 | 48 | 1194.01 |
| 49 | 7015 87 | 49 | 3154.03 | 49 | 2034.37 | 49 | 1501.48 | 49 | 1189.88 |
| 50 | 6875.55 | 50 | 3125.36 | 50 | 2022.41 | 50 | 1494.95 | 50 | 1185.78 |
| 51 | 6740.74 | 51 | 3097.20 | 51 | 2010.59 | 51 | 1488.48 | 51 | 1181.71 |
| 52 | 6611.12 | 52 | 3069.55 | 52 | 1998.90 | 52 | 1482.07 | 52 | 1177.66 |
| 53 | 6486.38 | 53 | 3042.39 | 53 | 1987.35 | 53 | 1475.71 | 53 | 1173.65 |
| 54 | 6366.26 | 54 | 3015.71 | 54 | 1975.93 | 54 | 1469.41 | 54 | 1169.66 |
| 55 | 6250.51 | 55 | 2989.48 | 55 | 1964.64 | 55 | 1463.16 | 55 | 1165.70 |
| 56 | 6138.90 | 56 | 2965.71 | 56 | 1953.48 | 56 | 1456.96 | 56 | 1161.76 |
| 57 | 6031.20 | 57 | 2938.39 | 57 | 1942.44 | 57 | 1450.81 | 57 | 1157.85 |
| 58 | 5927.22 | 58 | 2913.49 | 58 | 1931.53 | 58 | 1444.72 | 58 | 1153.97 |
| 59 | 5826.76 | 59 | 2889.01 | 59 | 1920.75 | 59 | 1438.68 | 59 | 1150.11 |
| 60 | 5729.65 | 60 | 2864.93 | 60 | 1910.08 | 60 | 1432.69 | 60 | 1146.28 |

## TABLE I.—RADII.

| Deg. | Radius. | Deg. | Radius. | Deg. | Radius. | Deg. | Radius. | Deg. | Radius. |
|---|---|---|---|---|---|---|---|---|---|
| 5° 0′ | 1146.28 | 6° 0′ | 955.37 | 7° 0′ | 818.64 | 8° 0′ | 716.34 | 9° 0′ | 636.78 |
| 1 | 1142.47 | 1 | 952.72 | 1 | 816.70 | 1 | 714.85 | 1 | 635.61 |
| 2 | 1138.69 | 2 | 950.09 | 2 | 814.76 | 2 | 713.37 | 2 | 634.44 |
| 3 | 1134.94 | 3 | 947.48 | 3 | 812.83 | 3 | 711.90 | 3 | 633.27 |
| 4 | 1131.21 | 4 | 944.83 | 4 | 810.92 | 4 | 710.43 | 4 | 632.10 |
| 5 | 1127.50 | 5 | 942.29 | 5 | 809.01 | 5 | 708.96 | 5 | 630.94 |
| 6 | 1123.82 | 6 | 939.72 | 6 | 807.11 | 6 | 707.51 | 6 | 629.79 |
| 7 | 1120.16 | 7 | 937.16 | 7 | 805.22 | 7 | 706.05 | 7 | 628.64 |
| 8 | 1116.52 | 8 | 934.62 | 8 | 803.34 | 8 | 704.60 | 8 | 627.49 |
| 9 | 1112.91 | 9 | 932.09 | 9 | 801.47 | 9 | 703.16 | 9 | 626.35 |
| 10 | 1109.33 | 10 | 929.57 | 10 | 799.61 | 10 | 701.73 | 10 | 625.21 |
| 11 | 1105.76 | 11 | 927.07 | 11 | 797.75 | 11 | 700.30 | 11 | 624.08 |
| 12 | 1102.22 | 12 | 924.58 | 12 | 795.91 | 12 | 698.88 | 12 | 622.95 |
| 13 | 1098.70 | 13 | 922.10 | 13 | 794.07 | 13 | 697.46 | 13 | 621.82 |
| 14 | 1095.20 | 14 | 919.64 | 14 | 792.24 | 14 | 696.05 | 14 | 620.70 |
| 15 | 1091.73 | 15 | 917.19 | 15 | 790.42 | 15 | 694.65 | 15 | 619.58 |
| 16 | 1088.28 | 16 | 914.75 | 16 | 788.61 | 16 | 693.24 | 16 | 618.47 |
| 17 | 1084.85 | 17 | 912.33 | 17 | 786.80 | 17 | 691.85 | 17 | 617.36 |
| 18 | 1081.44 | 18 | 909.92 | 18 | 785.01 | 18 | 690.46 | 18 | 616.25 |
| 19 | 1078.05 | 19 | 907.52 | 19 | 783.22 | 19 | 689.08 | 19 | 615.15 |
| 20 | 1074.68 | 20 | 905.13 | 20 | 781.44 | 20 | 687.70 | 20 | 614.05 |
| 21 | 1071.34 | 21 | 902.76 | 21 | 779.67 | 21 | 686.33 | 21 | 612.96 |
| 22 | 1068.01 | 22 | 900.40 | 22 | 777.91 | 22 | 684.96 | 22 | 611.87 |
| 23 | 1064.71 | 23 | 898.05 | 23 | 776.15 | 23 | 683.60 | 23 | 610.78 |
| 24 | 1061.43 | 24 | 895.71 | 24 | 774.40 | 24 | 682.25 | 24 | 609.70 |
| 25 | 1058.16 | 25 | 893.39 | 25 | 772.66 | 25 | 680.89 | 25 | 608.62 |
| 26 | 1054.92 | 26 | 891.08 | 26 | 770.93 | 26 | 679.55 | 26 | 607.55 |
| 27 | 1051.70 | 27 | 888.78 | 27 | 769.21 | 27 | 678.21 | 27 | 606.48 |
| 28 | 1048.48 | 28 | 886.49 | 28 | 767.49 | 28 | 676.88 | 28 | 605.41 |
| 29 | 1045.31 | 29 | 884.21 | 29 | 765.78 | 29 | 675.54 | 29 | 604.35 |
| 30 | 1042.14 | 30 | 881.95 | 30 | 764.08 | 30 | 674.22 | 30 | 603.29 |
| 31 | 1039.00 | 31 | 879.69 | 31 | 762.39 | 31 | 672.90 | 31 | 602.23 |
| 32 | 1035.87 | 32 | 877.45 | 32 | 760.70 | 32 | 671.59 | 32 | 601.18 |
| 33 | 1032.76 | 33 | 875.22 | 33 | 759.02 | 33 | 670.28 | 33 | 600.13 |
| 34 | 1029.67 | 34 | 873.00 | 34 | 757.35 | 34 | 668.98 | 34 | 599.00 |
| 35 | 1026.60 | 35 | 870.80 | 35 | 755.69 | 35 | 667.68 | 35 | 598.04 |
| 36 | 1023.55 | 36 | 868.60 | 36 | 754.03 | 36 | 666.39 | 36 | 597.01 |
| 37 | 1020.51 | 37 | 866.41 | 37 | 752.38 | 37 | 665.10 | 37 | 595.97 |
| 38 | 1017.49 | 38 | 864.24 | 38 | 750.74 | 38 | 663.82 | 38 | 594.94 |
| 39 | 1014.50 | 39 | 862.08 | 39 | 749.10 | 39 | 662.54 | 39 | 593.91 |
| 40 | 1011.51 | 40 | 859.92 | 40 | 747.48 | 40 | 661.26 | 40 | 592.89 |
| 41 | 1008.55 | 41 | 857.78 | 41 | 745.86 | 41 | 659.99 | 41 | 591.87 |
| 42 | 1005.60 | 42 | 855.65 | 42 | 744.24 | 42 | 658.73 | 42 | 590.85 |
| 43 | 1002.67 | 43 | 853.53 | 43 | 742.63 | 43 | 657.47 | 43 | 589.84 |
| 44 | 999.76 | 44 | 851.42 | 44 | 741.03 | 44 | 656.22 | 44 | 588.83 |
| 45 | 996.87 | 45 | 849.32 | 45 | 739.44 | 45 | 654.97 | 45 | 587.83 |
| 46 | 993.99 | 46 | 847.23 | 46 | 737.86 | 46 | 653.72 | 46 | 586.82 |
| 47 | 991.13 | 47 | 845.15 | 47 | 736.28 | 47 | 652.48 | 47 | 585.83 |
| 48 | 988.28 | 48 | 843.08 | 48 | 734.70 | 48 | 651.25 | 48 | 584.83 |
| 49 | 985.45 | 49 | 841.02 | 49 | 733.14 | 49 | 650.02 | 49 | 583.84 |
| 50 | 982.64 | 50 | 838.97 | 50 | 731.58 | 50 | 648.79 | 50 | 582.85 |
| 51 | 979.84 | 51 | 836.93 | 51 | 730.03 | 51 | 647.57 | 51 | 581.86 |
| 52 | 977.06 | 52 | 834.90 | 52 | 728.48 | 52 | 646.35 | 52 | 580.88 |
| 53 | 974.29 | 53 | 832.89 | 53 | 726.94 | 53 | 645.14 | 53 | 579.90 |
| 54 | 971.54 | 54 | 830.88 | 54 | 725.41 | 54 | 643.94 | 54 | 578.92 |
| 55 | 968.81 | 55 | 828.88 | 55 | 723.88 | 55 | 642.73 | 55 | 577.95 |
| 56 | 966.09 | 56 | 826.89 | 56 | 722.36 | 56 | 641.53 | 56 | 576.98 |
| 57 | 963.39 | 57 | 824.91 | 57 | 720.85 | 57 | 640.34 | 57 | 576.02 |
| 58 | 960.70 | 58 | 822.93 | 58 | 719.34 | 58 | 639.15 | 58 | 575.06 |
| 59 | 958.03 | 59 | 820.97 | 59 | 717.84 | 59 | 637.96 | 59 | 574.10 |
| 60 | 955.37 | 60 | 819.02 | 60 | 716.34 | 60 | 636.78 | 60 | 573.14 |

## TABLE I.—RADII.

| Deg. | Radius. | Deg. | Radius. | Deg. | Radius. | Deg. | Radius. | Deg. | Radius. |
|---|---|---|---|---|---|---|---|---|---|
| 10° 0′ | 573.14 | 12° 0′ | 477.68 | 14° 0′ | 409.32 | 16° 0′ | 358.17 | 18° 0′ | 318.39 |
| 2 | 571.24 | 2 | 476.36 | 2 | 408.35 | 2 | 357.43 | 2 | 317.80 |
| 4 | 569.35 | 4 | 475.05 | 4 | 407.38 | 4 | 356.69 | 4 | 317.22 |
| 6 | 567.47 | 6 | 473.74 | 6 | 406.42 | 6 | 355.95 | 6 | 316.63 |
| 8 | 565.60 | 8 | 472.44 | 8 | 405.46 | 8 | 355.21 | 8 | 316.05 |
| 10 | 563.75 | 10 | 471.15 | 10 | 404.51 | 10 | 354.48 | 10 | 315.47 |
| 12 | 561.91 | 12 | 469.86 | 12 | 403.56 | 12 | 353.75 | 12 | 314.89 |
| 14 | 560.08 | 14 | 468.58 | 14 | 402.61 | 14 | 353.03 | 14 | 314.32 |
| 16 | 558.26 | 16 | 467.31 | 16 | 401.67 | 16 | 352.30 | 16 | 313.75 |
| 18 | 556.45 | 18 | 466.04 | 18 | 400.74 | 18 | 351.58 | 18 | 313.18 |
| 20 | 554.66 | 20 | 464.78 | 20 | 399.80 | 20 | 350.86 | 20 | 312.61 |
| 22 | 552.88 | 22 | 463.53 | 22 | 398.88 | 22 | 350.15 | 22 | 312.04 |
| 24 | 551.11 | 24 | 462.29 | 24 | 397.95 | 24 | 349.44 | 24 | 311.47 |
| 26 | 549.35 | 26 | 461.05 | 26 | 397.03 | 26 | 348.72 | 26 | 310.91 |
| 28 | 547.60 | 28 | 459.82 | 28 | 396.13 | 28 | 348.02 | 28 | 310.35 |
| 30 | 545.87 | 30 | 458.59 | 30 | 395.21 | 30 | 347.32 | 30 | 309.79 |
| 32 | 544.14 | 32 | 457.38 | 32 | 394.30 | 32 | 346.62 | 32 | 309.23 |
| 34 | 542.42 | 34 | 456.16 | 34 | 393.40 | 34 | 345.93 | 34 | 308.68 |
| 36 | 540.72 | 36 | 454.96 | 36 | 392.50 | 36 | 345.23 | 36 | 308.13 |
| 38 | 539.03 | 38 | 453.76 | 38 | 391.61 | 38 | 344.54 | 38 | 307.58 |
| 40 | 537.34 | 40 | 452.57 | 40 | 390.72 | 40 | 343.85 | 40 | 307.03 |
| 42 | 535.67 | 42 | 451.38 | 42 | 389.83 | 42 | 343.16 | 42 | 306.48 |
| 44 | 534.01 | 44 | 450.20 | 44 | 388.95 | 44 | 342.48 | 44 | 305.93 |
| 46 | 532.36 | 46 | 449.02 | 46 | 388.07 | 46 | 341.80 | 46 | 305.39 |
| 48 | 530.71 | 48 | 447.86 | 48 | 387.20 | 48 | 341.12 | 48 | 304.85 |
| 50 | 529.08 | 50 | 446.69 | 50 | 386.33 | 50 | 340.45 | 50 | 304.31 |
| 52 | 527.46 | 52 | 445.54 | 52 | 385.47 | 52 | 339.78 | 52 | 303.77 |
| 54 | 525.85 | 54 | 444.39 | 54 | 384.60 | 54 | 339.11 | 54 | 303.24 |
| 56 | 524.25 | 56 | 443.24 | 56 | 383.75 | 56 | 338.44 | 56 | 302.70 |
| 58 | 522.65 | 58 | 442.11 | 58 | 382.89 | 58 | 337.77 | 58 | 302.17 |
| 11° 0′ | 521.07 | 13° 0′ | 440.97 | 15° 0′ | 382.04 | 17° 0′ | 337.11 | 19° 0′ | 301.64 |
| 2 | 519.50 | 2 | 439.85 | 2 | 381.19 | 2 | 336.45 | 2 | 301.12 |
| 4 | 517.93 | 4 | 438.73 | 4 | 380.35 | 4 | 335.80 | 4 | 300.59 |
| 6 | 516.38 | 6 | 437.61 | 6 | 379.51 | 6 | 335.14 | 6 | 300.07 |
| 8 | 514.84 | 8 | 436.50 | 8 | 378.68 | 8 | 334.49 | 8 | 299.54 |
| 10 | 513.30 | 10 | 435.40 | 10 | 377.84 | 10 | 333.84 | 10 | 299.02 |
| 12 | 511.77 | 12 | 434.30 | 12 | 377.02 | 12 | 333.19 | 12 | 298.50 |
| 14 | 510.26 | 14 | 433.21 | 14 | 376.19 | 14 | 332.55 | 14 | 297.99 |
| 16 | 508.75 | 16 | 432.12 | 16 | 375.37 | 16 | 331.91 | 16 | 297.47 |
| 18 | 507.25 | 18 | 431.04 | 18 | 374.55 | 18 | 331.27 | 18 | 296.96 |
| 20 | 505.76 | 20 | 429.96 | 20 | 373.74 | 20 | 330.63 | 20 | 296.45 |
| 22 | 504.28 | 22 | 428.98 | 22 | 372.93 | 22 | 330.00 | 22 | 295.94 |
| 24 | 502.80 | 24 | 427.82 | 24 | 372.12 | 24 | 329.37 | 24 | 295.43 |
| 26 | 501.34 | 26 | 426.76 | 26 | 371.32 | 26 | 328.74 | 26 | 294.92 |
| 28 | 499.88 | 28 | 425.71 | 28 | 370.52 | 28 | 328.11 | 28 | 294.42 |
| 30 | 498.43 | 30 | 424.66 | 30 | 369.72 | 30 | 327.48 | 30 | 293.91 |
| 32 | 496.99 | 32 | 423.61 | 32 | 368.93 | 32 | 326.86 | 32 | 293.41 |
| 34 | 495.56 | 34 | 422.57 | 34 | 368.14 | 34 | 326.24 | 34 | 292.91 |
| 36 | 494.14 | 36 | 421.54 | 36 | 367.35 | 36 | 325.62 | 36 | 292.41 |
| 38 | 492.73 | 38 | 420.51 | 38 | 366.57 | 38 | 325.01 | 38 | 291.92 |
| 40 | 491.32 | 40 | 419.49 | 40 | 365.79 | 40 | 324.40 | 40 | 291.42 |
| 42 | 489.92 | 42 | 418.47 | 42 | 365.01 | 42 | 323.79 | 42 | 290.93 |
| 44 | 488.53 | 44 | 417.45 | 44 | 364.24 | 44 | 323.18 | 44 | 290.44 |
| 46 | 487.15 | 46 | 416.44 | 46 | 363.47 | 46 | 322.57 | 46 | 289.95 |
| 48 | 485.77 | 48 | 415.44 | 48 | 362.70 | 48 | 321.97 | 48 | 289.46 |
| 50 | 484.40 | 50 | 414.44 | 50 | 361.94 | 50 | 321.37 | 50 | 288.98 |
| 52 | 483.05 | 52 | 413.44 | 52 | 361.18 | 52 | 320.77 | 52 | 288.49 |
| 54 | 481.69 | 54 | 412.45 | 54 | 360.42 | 54 | 320.17 | 54 | 288.01 |
| 56 | 480.35 | 56 | 411.47 | 56 | 359.67 | 56 | 319.57 | 56 | 287.53 |
| 58 | 479.01 | 58 | 410.49 | 58 | 358.92 | 58 | 318.98 | 58 | 287.05 |
| 60 | 477.68 | 60 | 409.51 | 60 | 358.17 | 60 | 318.39 | 60 | 286.57 |

## TABLE I*a*.—RADII OF METRIC CURVES—20 M. CHORDS.

| Def. Ang. | Radius, Meters. | Def. Ang. | Radius, Meters. | Def. Ang. | Radius, Meters. | Def. Ang. | Radius, Meters. | Def. Ang. | Radius, Meters. |
|---|---|---|---|---|---|---|---|---|---|
| 0° 0′ | Infinite | 2° 0′ | 286.54 | 4° 0′ | 143.36 | 6° 0′ | 95.67 | 8° 0′ | 71.85 |
| 2 | 17188.74 | 2 | 281.84 | 2 | 142.17 | 2 | 95.14 | 2 | 71.56 |
| 4 | 8594.37 | 4 | 277.30 | 4 | 141.01 | 4 | 94.62 | 4 | 71.26 |
| 6 | 5729.58 | 6 | 272.90 | 6 | 139.87 | 6 | 94.11 | 6 | 70.97 |
| 8 | 4297.19 | 8 | 268.64 | 8 | 138.74 | 8 | 93.60 | 8 | 70.68 |
| 10 | 3437.75 | 10 | 264.51 | 10 | 137.63 | 10 | 93.09 | 10 | 70.40 |
| 12 | 2864.79 | 12 | 260.50 | 12 | 136.54 | 12 | 92.59 | 12 | 70.11 |
| 14 | 2455.54 | 14 | 256.61 | 14 | 135.47 | 14 | 92.10 | 14 | 69.83 |
| 16 | 2148.60 | 16 | 252.84 | 16 | 134.41 | 16 | 91.61 | 16 | 69.55 |
| 18 | 1909.87 | 18 | 249.18 | 18 | 133.37 | 18 | 91.13 | 18 | 69.27 |
| 20 | 1718.88 | 20 | 245.62 | 20 | 132.35 | 20 | 90.65 | 20 | 69.00 |
| 22 | 1562.62 | 22 | 242.16 | 22 | 131.34 | 22 | 90.18 | 22 | 68.73 |
| 24 | 1432.41 | 24 | 238.80 | 24 | 130.35 | 24 | 89.71 | 24 | 68.45 |
| 26 | 1322.22 | 26 | 235.54 | 26 | 129.37 | 26 | 89.25 | 26 | 68.19 |
| 28 | 1227.78 | 28 | 232.35 | 28 | 128.40 | 28 | 88.79 | 28 | 67.92 |
| 30 | 1145.93 | 30 | 229.26 | 30 | 127.45 | 30 | 88.34 | 30 | 67.65 |
| 32 | 1074.31 | 32 | 226.24 | 32 | 126.52 | 32 | 87.89 | 32 | 67.39 |
| 34 | 1011.12 | 34 | 223.31 | 34 | 125.60 | 34 | 87.44 | 34 | 67.13 |
| 36 | 954.95 | 36 | 220.44 | 36 | 124.69 | 36 | 87.00 | 36 | 66.87 |
| 38 | 904.69 | 38 | 217.66 | 38 | 123.79 | 38 | 86.57 | 38 | 66.62 |
| 40 | 859.46 | 40 | 214.94 | 40 | 122.91 | 40 | 86.14 | 40 | 66.36 |
| 42 | 818.53 | 42 | 212.29 | 42 | 122.04 | 42 | 85.71 | 42 | 66.11 |
| 44 | 781.33 | 44 | 209.70 | 44 | 121.19 | 44 | 85.29 | 44 | 65.86 |
| 46 | 747.36 | 46 | 207.17 | 46 | 120.34 | 46 | 84.87 | 46 | 65.61 |
| 48 | 716.23 | 48 | 204.71 | 48 | 119.51 | 48 | 84.46 | 48 | 65.37 |
| 50 | 687.57 | 50 | 202.30 | 50 | 118.68 | 50 | 84.05 | 50 | 65.12 |
| 52 | 661.13 | 52 | 199.95 | 52 | 117.87 | 52 | 83.64 | 52 | 64.88 |
| 54 | 636.65 | 54 | 197.66 | 54 | 117.07 | 54 | 83.24 | 54 | 64.64 |
| 56 | 613.91 | 56 | 195.41 | 56 | 116.28 | 56 | 82.84 | 56 | 64.40 |
| 58 | 592.74 | 58 | 193.22 | 58 | 115.51 | 58 | 82.45 | 58 | 64.16 |
| 1° 0′ | 572.99 | 3° 0′ | 191.07 | 5° 0′ | 114.74 | 7° 0′ | 82.06 | 9° 0′ | 63.92 |
| 2 | 554.51 | 2 | 188.98 | 2 | 113.98 | 2 | 81.67 | 2 | 63.69 |
| 4 | 537.18 | 4 | 186.92 | 4 | 113.23 | 4 | 81.28 | 4 | 63.46 |
| 6 | 520.90 | 6 | 184.92 | 6 | 112.49 | 6 | 80.91 | 6 | 63.23 |
| 8 | 505.58 | 8 | 182.95 | 8 | 111.76 | 8 | 80.53 | 8 | 63.00 |
| 10 | 491.14 | 10 | 181.03 | 10 | 111.05 | 10 | 80.16 | 10 | 62.77 |
| 12 | 477.50 | 12 | 179.14 | 12 | 110.34 | 12 | 79.79 | 12 | 62.55 |
| 14 | 464.60 | 14 | 177.30 | 14 | 109.63 | 14 | 79.42 | 14 | 62.32 |
| 16 | 452.37 | 16 | 175.49 | 16 | 108.94 | 16 | 79.06 | 16 | 62.10 |
| 18 | 440.77 | 18 | 173.72 | 18 | 108.26 | 18 | 78.70 | 18 | 61.88 |
| 20 | 429.76 | 20 | 171.98 | 20 | 107.58 | 20 | 78.34 | 20 | 61.66 |
| 22 | 419.28 | 22 | 170.28 | 22 | 106.92 | 22 | 77.99 | 22 | 61.44 |
| 24 | 409.30 | 24 | 168.62 | 24 | 106.26 | 24 | 77.64 | 24 | 61.23 |
| 26 | 399.78 | 26 | 166.98 | 26 | 105.61 | 26 | 77.30 | 26 | 61.01 |
| 28 | 390.70 | 28 | 165.38 | 28 | 104.97 | 28 | 76.95 | 28 | 60.80 |
| 30 | 382.02 | 30 | 163.80 | 30 | 104.33 | 30 | 76.61 | 30 | 60.59 |
| 32 | 373.71 | 32 | 162.26 | 32 | 103.71 | 32 | 76.28 | 32 | 60.38 |
| 34 | 365.76 | 34 | 160.75 | 34 | 103.09 | 34 | 75.94 | 34 | 60.17 |
| 36 | 358.15 | 36 | 159.26 | 36 | 102.48 | 36 | 75.61 | 36 | 59.96 |
| 38 | 350.84 | 38 | 157.80 | 38 | 101.87 | 38 | 75.28 | 38 | 59.76 |
| 40 | 343.82 | 40 | 156.37 | 40 | 101.28 | 40 | 74.96 | 40 | 59.55 |
| 42 | 337.08 | 42 | 154.96 | 42 | 100.68 | 42 | 74.63 | 42 | 59.35 |
| 44 | 330.60 | 44 | 153.58 | 44 | 100.10 | 44 | 74.31 | 44 | 59.15 |
| 46 | 324.37 | 46 | 152.22 | 46 | 99.52 | 46 | 74.00 | 46 | 58.95 |
| 48 | 318.36 | 48 | 150.89 | 48 | 98.95 | 48 | 73.68 | 48 | 58.75 |
| 50 | 312.58 | 50 | 149.58 | 50 | 98.39 | 50 | 73.37 | 50 | 58.55 |
| 52 | 307.00 | 52 | 148.29 | 52 | 97.83 | 52 | 73.06 | 52 | 58.36 |
| 54 | 301.61 | 54 | 147.03 | 54 | 97.28 | 54 | 72.76 | 54 | 58.16 |
| 56 | 296.41 | 56 | 145.78 | 56 | 96.74 | 56 | 72.45 | 56 | 57.97 |
| 58 | 291.39 | 58 | 144.56 | 58 | 96.20 | 58 | 72.15 | 58 | 57.78 |
| 60 | 286.54 | 60 | 143.36 | 60 | 95.67 | 60 | 71.85 | 60 | 57.59 |

| ′ | 0″ | 10″ | 15″ | 20″ | 30″ | 40″ | 45″ | 50″ | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | .00000 | 00278 | .00417 | .00556 | .00833 | .01111 | .01250 | .01389 | 0 |
| 1 | .01667 | .01944 | .02083 | .02222 | .02500 | .02778 | .02917 | .03055 | 1 |
| 2 | .03333 | .03611 | .03750 | .03889 | .04167 | .04444 | .04583 | .04722 | 2 |
| 3 | .05000 | .05278 | .05417 | .05556 | .05833 | .06111 | .06250 | .06389 | 3 |
| 4 | .06667 | .06944 | .07083 | .07222 | .07500 | .07778 | .07917 | .08056 | 4 |
| 5 | .08333 | .08611 | .08750 | .08889 | .09167 | .09444 | .09583 | .09722 | 5 |
| 6 | .10000 | .10278 | .10417 | .10556 | .10833 | .11111 | .11250 | .11389 | 6 |
| 7 | .11667 | .11944 | .12083 | .12222 | .12500 | .12778 | .12917 | .13056 | 7 |
| 8 | .13333 | .13611 | .13750 | .13889 | .14167 | .14444 | .14583 | .14722 | 8 |
| 9 | .15000 | .15278 | .15417 | .15556 | .15833 | .16111 | .16250 | .16389 | 9 |
| 10 | .16667 | .16944 | .17083 | .17222 | .17500 | .17778 | .17917 | .18056 | 10 |
| 11 | .18333 | .18611 | .18750 | .18889 | .19167 | .19444 | .19583 | .19722 | 11 |
| 12 | .20000 | .20278 | .20417 | .20556 | .20833 | .21111 | .21250 | .21389 | 12 |
| 13 | .21667 | .21944 | .22083 | .22222 | .22500 | .22778 | .22917 | .23056 | 13 |
| 14 | .23333 | .23611 | .23750 | .23889 | .24167 | .24444 | .24583 | .24722 | 14 |
| 15 | .25000 | .25278 | .25417 | .25556 | .25833 | .26111 | .26250 | .26389 | 15 |
| 16 | .26667 | .26944 | .27083 | .27222 | .27500 | .27778 | .27917 | .28056 | 16 |
| 17 | .28333 | .28611 | .28750 | .28889 | .29167 | .29444 | .29583 | .29722 | 17 |
| 18 | .30000 | .30278 | .30417 | .30556 | .30833 | .31111 | .31250 | .31389 | 18 |
| 19 | .31667 | .31944 | .32083 | .32222 | .32500 | .32778 | .32917 | .33056 | 19 |
| 20 | .33333 | .33611 | .33750 | .33889 | .34167 | .34444 | .34583 | .34722 | 20 |
| 21 | .35000 | .35278 | .35417 | .35556 | .35833 | .36111 | .36250 | .36389 | 21 |
| 22 | .36667 | .36944 | .37083 | .37222 | .37500 | .37778 | .37917 | .38056 | 22 |
| 23 | .38333 | .38611 | .38750 | .38889 | .39167 | .39444 | .39583 | .39722 | 23 |
| 24 | .40000 | .40278 | .40417 | .40556 | .40833 | .41111 | .41250 | .41389 | 24 |
| 25 | .41667 | .41944 | .42083 | .42222 | .42500 | .42778 | .42917 | .43056 | 25 |
| 26 | .43333 | .43611 | .43750 | .43889 | .44167 | .44444 | .44583 | .44722 | 26 |
| 27 | .45000 | .45278 | .45417 | .45556 | .45833 | .46111 | .46250 | .46389 | 27 |
| 28 | .46667 | .46944 | .47083 | .47222 | .47500 | .47778 | .47917 | .48056 | 28 |
| 29 | .48333 | .48611 | .48750 | .48889 | .49167 | .49444 | .49583 | .49722 | 29 |
| 30 | .50000 | .50278 | .50417 | .50556 | .50833 | .51111 | .51250 | .51389 | 30 |
| 31 | .51667 | .51944 | .52083 | .52222 | .52500 | .52778 | .52917 | .53056 | 31 |
| 32 | .53333 | .53611 | .53750 | .53889 | .54167 | .54444 | .54583 | .54722 | 32 |
| 33 | .55000 | .55278 | .55417 | .55556 | .55833 | .56111 | .56250 | .56389 | 33 |
| 34 | .56667 | .56944 | .57083 | .57222 | .57500 | .57778 | .57917 | .58056 | 34 |
| 35 | .58333 | .58611 | .58750 | .58889 | .59167 | .59444 | .59583 | .59722 | 35 |
| 36 | .60000 | .60278 | .60417 | .60556 | .60833 | .61111 | .61250 | .61389 | 36 |
| 37 | .61667 | .61944 | .62083 | .62222 | .62500 | .62778 | .62917 | .63056 | 37 |
| 38 | .63333 | .63611 | .63750 | .63889 | .64167 | .64444 | .64583 | .64722 | 38 |
| 39 | .65000 | .65278 | .65417 | .65556 | .65833 | .66111 | .66250 | .66389 | 39 |
| 40 | .66667 | .66944 | .67083 | .67222 | .67500 | .67778 | .67917 | .68056 | 40 |
| 41 | .68333 | .68611 | .68750 | .68889 | .69167 | .69444 | .69583 | .69722 | 41 |
| 42 | .70000 | .70278 | .70417 | .70556 | .70833 | .71111 | .71250 | .71389 | 42 |
| 43 | .71667 | .71944 | .72083 | .72222 | .72500 | .72778 | .72917 | .73056 | 43 |
| 44 | .73333 | .73611 | .73750 | .73889 | .74167 | .74444 | .74583 | .74722 | 44 |
| 45 | .75000 | .75278 | .75417 | .75556 | .75833 | .76111 | .76250 | .76389 | 45 |
| 46 | .76667 | .76944 | .77083 | .77222 | .77500 | .77778 | .77917 | .78056 | 46 |
| 47 | .78333 | .78611 | .78750 | .78889 | .79167 | .79414 | .79583 | .79722 | 47 |
| 48 | .80000 | .80278 | .80417 | .80556 | .80833 | .81111 | .81250 | .81389 | 48 |
| 49 | .81667 | .81944 | .82083 | .82222 | .82500 | .82778 | .82917 | .83056 | 49 |
| 50 | .83333 | .83611 | .83750 | .83889 | .84167 | .84444 | .84583 | .84722 | 50 |
| 51 | .85000 | .85278 | .85417 | .85556 | .85833 | 86111 | .86250 | .86389 | 51 |
| 52 | .86667 | .86944 | .87083 | .87222 | .87500 | .87778 | .87917 | .88056 | 52 |
| 53 | .88333 | .88611 | .88750 | .88889 | .89167 | .89444 | .89583 | .89722 | 53 |
| 54 | .90000 | .90278 | .90417 | .90556 | .90833 | .91111 | .91250 | .91389 | 54 |
| 55 | .91667 | .91944 | .92083 | .92222 | .92500 | .92778 | .92917 | .93056 | 55 |
| 56 | .93333 | .93611 | .93750 | .93889 | .94167 | .94444 | .94583 | .94722 | 56 |
| 57 | .95000 | .95278 | .95417 | .95556 | .95833 | .96111 | .96250 | .96389 | 57 |
| 58 | .96667 | .96944 | .97083 | .97222 | .97500 | .97778 | .97917 | .98056 | 58 |
| 59 | .98333 | .98611 | .98750 | .98889 | .99167 | .99444 | .99583 | .99722 | 59 |
| ′ | 0″ | 10″ | 15″ | 20″ | 30″ | 40″ | 45″ | 50″ | ′ |

## TABLE III.—TANGENTIAL OFFSETS.

| | OFFSETS 100 FEET ALONG CURVE. | | | | | | | | OFFSETS 50 FEET ALONG CURVE. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deg. of Curve. | 0° | 1° | 2° | 3° | 4° | 5° | 6° | Deg. of Curve. | 7° | 8° | 9° | 10° | 11° | 12° | 13° |
| 0′ | 0.00 | 0.87 | 1.75 | 2.62 | 3.49 | 4.36 | 5.23 | 0′ | 1.53 | 1.75 | 1.96 | 2.18 | 2.40 | 2.62 | 2.84 |
| 2 | 0.03 | 0.90 | 1.77 | 2.65 | 3.52 | 4.39 | 5.26 | 2 | 1.53 | 1.75 | 1.97 | 2.19 | 2.41 | 2.62 | 2.84 |
| 4 | 0.06 | 0.93 | 1.80 | 2.68 | 3.55 | 4.42 | 5.29 | 4 | 1.54 | 1.76 | 1.98 | 2.20 | 2.41 | 2.63 | 2.85 |
| 6 | 0.09 | 0.96 | 1.83 | 2.71 | 3.58 | 4.45 | 5.32 | 6 | 1.55 | 1.77 | 1.99 | 2.20 | 2.42 | 2.64 | 2.86 |
| 8 | 0.12 | 0.99 | 1.86 | 2.73 | 3.61 | 4.48 | 5.35 | 8 | 1.56 | 1.77 | 1.99 | 2.21 | 2.43 | 2.65 | 2.86 |
| 10 | 0.15 | 1.02 | 1.89 | 2.76 | 3.64 | 4.51 | 5.38 | 10 | 1.56 | 1.78 | 2.00 | 2.22 | 2.44 | 2.65 | 2.87 |
| 12 | 0.17 | 1.05 | 1.92 | 2.79 | 3.66 | 4.54 | 5.41 | 12 | 1.57 | 1.79 | 2.01 | 2.23 | 2.44 | 2.66 | 2.88 |
| 14 | 0.20 | 1.08 | 1.95 | 2.82 | 3.69 | 4.57 | 5.44 | 14 | 1.58 | 1.80 | 2.01 | 2.23 | 2.45 | 2.67 | 2.89 |
| 16 | 0.23 | 1.11 | 1.98 | 2.85 | 3.72 | 4.59 | 5.47 | 16 | 1.59 | 1.80 | 2.02 | 2.24 | 2.46 | 2.68 | 2.89 |
| 18 | 0.26 | 1.13 | 2.01 | 2.88 | 3.75 | 4.62 | 5.50 | 18 | 1.59 | 1.81 | 2.03 | 2.25 | 2.47 | 2.68 | 2.90 |
| 20 | 0.29 | 1.16 | 2.04 | 2.91 | 3.78 | 4.65 | 5.52 | 20 | 1.60 | 1.82 | 2.04 | 2.25 | 2.47 | 2.69 | 2.91 |
| 22 | 0.32 | 1.19 | 2.07 | 2.94 | 3.81 | 4.68 | 5.55 | 22 | 1.61 | 1.83 | 2.04 | 2.26 | 2.48 | 2.70 | 2.92 |
| 24 | 0.35 | 1.22 | 2.09 | 2.97 | 3.84 | 4.71 | 5.58 | 24 | 1.61 | 1.83 | 2.05 | 2.27 | 2.49 | 2.70 | 2.92 |
| 26 | 0.38 | 1.25 | 2.12 | 3.00 | 3.87 | 4.74 | 5.61 | 26 | 1.62 | 1.84 | 2.06 | 2.28 | 2.49 | 2.71 | 2.93 |
| 28 | 0.41 | 1.28 | 2.15 | 3.02 | 3.90 | 4.77 | 5.64 | 28 | 1.63 | 1.85 | 2.07 | 2.28 | 2.50 | 2.72 | 2.94 |
| 30 | 0.44 | 1.31 | 2.18 | 3.05 | 3.93 | 4.80 | 5.67 | 30 | 1.64 | 1.85 | 2.07 | 2.29 | 2.51 | 2.73 | 2.94 |
| 32 | 0.47 | 1.34 | 2.21 | 3.08 | 3.96 | 4.83 | 5.70 | 32 | 1.64 | 1.86 | 2.08 | 2.30 | 2.52 | 2.73 | 2.95 |
| 34 | 0.49 | 1.37 | 2.24 | 3.11 | 3.98 | 4.86 | 5.73 | 34 | 1.65 | 1.87 | 2.09 | 2.31 | 2.52 | 2.74 | 2.96 |
| 36 | 0.52 | 1.40 | 2.27 | 3.14 | 4.01 | 4.89 | 5.76 | 36 | 1.66 | 1.88 | 2.09 | 2.31 | 2.53 | 2.75 | 2.97 |
| 38 | 0.55 | 1.43 | 2.30 | 3.17 | 4.04 | 4.91 | 5.79 | 38 | 1.67 | 1.88 | 2.10 | 2.32 | 2.54 | 2.76 | 2.97 |
| 40 | 0.58 | 1.45 | 2.33 | 3.20 | 4.07 | 4.94 | 5.81 | 40 | 1.67 | 1.89 | 2.11 | 2.33 | 2.55 | 2.76 | 2.98 |
| 42 | 0.61 | 1.48 | 2.36 | 3.23 | 4.10 | 4.97 | 5.84 | 42 | 1.68 | 1.90 | 2.12 | 2.33 | 2.55 | 2.77 | 2.99 |
| 44 | 0.64 | 1.51 | 2.39 | 3.26 | 4.13 | 5.00 | 5.87 | 44 | 1.69 | 1.91 | 2.12 | 2.34 | 2.56 | 2.78 | 3.00 |
| 46 | 0.67 | 1.54 | 2.41 | 3.29 | 4.16 | 5.03 | 5.90 | 46 | 1.69 | 1.91 | 2.13 | 2.35 | 2.57 | 2.79 | 3.00 |
| 48 | 0.70 | 1.57 | 2.44 | 3.32 | 4.19 | 5.06 | 5.93 | 48 | 1.70 | 1.92 | 2.14 | 2.36 | 2.57 | 2.79 | 3.01 |
| 50 | 0.73 | 1.60 | 2.47 | 3.35 | 4.22 | 5.09 | 5.96 | 50 | 1.71 | 1.93 | 2.15 | 2.36 | 2.58 | 2.80 | 3.02 |
| 52 | 0.76 | 1.63 | 2.50 | 3.37 | 4.25 | 5.12 | 5.99 | 52 | 1.72 | 1.93 | 2.15 | 2.37 | 2.59 | 2.81 | 3.02 |
| 54 | 0.79 | 1.66 | 2.53 | 3.40 | 4.28 | 5.15 | 6.02 | 54 | 1.72 | 1.94 | 2.16 | 2.38 | 2.60 | 2.81 | 3.03 |
| 56 | 0.81 | 1.69 | 2.56 | 3.43 | 4.30 | 5.18 | 6.05 | 56 | 1.73 | 1.95 | 2.17 | 2.39 | 2.60 | 2.82 | 3.04 |
| 58 | 0.84 | 1.72 | 2.59 | 3.46 | 4.33 | 5.20 | 6.08 | 58 | 1.74 | 1.96 | 2.17 | 2.39 | 2.61 | 2.83 | 3.05 |
| 60 | 0.87 | 1.75 | 2.62 | 3.49 | 4.36 | 5.23 | 6.11 | 60 | 1.75 | 1.96 | 2.18 | 2.40 | 2.62 | 2.84 | 3.05 |

## TABLE IV.—LONG CHORDS.

| Degree of Curve. | | Actual Arc, One Station. | Long Chords. | | | | |
|---|---|---|---|---|---|---|---|
| | | | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
| 0° | 10′ | 100.000 | 200.00 | 300.00 | 400.00 | 500.00 | 599.99 |
| | 20 | .000 | 200.00 | 300.00 | 399.99 | 499.98 | 599.97 |
| | 30 | .000 | 200.00 | 299.99 | 399.98 | 499.96 | 599.93 |
| | 40 | .001 | 200.00 | 299.99 | 399.97 | 499.93 | 599.88 |
| | 50 | .001 | 200.00 | 299.98 | 399.95 | 499.89 | 599.82 |
| 1 | | 100.001 | 199.99 | 299.97 | 399.92 | 499.85 | 599.73 |
| | 10 | .002 | 199.99 | 299.96 | 399.90 | 499.79 | 599.64 |
| | 20 | .002 | 199.99 | 299.95 | 399.87 | 499.73 | 599.53 |
| | 30 | .003 | 199.98 | 299.93 | 399.83 | 499.66 | 599.40 |
| | 40 | .003 | 199.98 | 299.92 | 399.79 | 499.58 | 599.26 |
| | 50 | .004 | 199.97 | 299.90 | 399.74 | 499.49 | 599.11 |
| 2 | | 100.005 | 199.97 | 299.88 | 399.70 | 499.39 | 598.93 |
| | 10 | .006 | 199.96 | 299.86 | 399.64 | 499.29 | 598.75 |
| | 20 | .007 | 199.96 | 299.83 | 399.59 | 499.17 | 598.55 |
| | 30 | .008 | 199.95 | 299.81 | 399.52 | 499.05 | 598.34 |
| | 40 | .009 | 199.95 | 299.78 | 399.46 | 498.92 | 598.11 |
| | 50 | .010 | 199.94 | 299.76 | 399.39 | 498.78 | 597.86 |
| 3 | | 100.011 | 199.93 | 299.73 | 399.32 | 498.63 | 597.60 |
| | 10 | .013 | 199.92 | 299.70 | 399.24 | 498.47 | 597.33 |
| | 20 | .014 | 199.92 | 299.66 | 399.15 | 498.31 | 597.04 |
| | 30 | .015 | 199.91 | 299.63 | 399.07 | 498.14 | 596.74 |
| | 40 | .017 | 199.90 | 299.59 | 398.98 | 497.96 | 596.42 |
| | 50 | .019 | 199.89 | 299.55 | 398.88 | 497.77 | 596.09 |
| 4 | | 100.020 | 199.88 | 299.51 | 398.78 | 497.57 | 595.74 |
| | 10 | .022 | 199.87 | 299.47 | 398.68 | 497.36 | 595.38 |
| | 20 | .024 | 199.86 | 299.43 | 398.57 | 497.15 | 595.01 |
| | 30 | .026 | 199.85 | 299.38 | 398.46 | 496.92 | 594.62 |
| | 40 | .028 | 199.83 | 299.34 | 398.34 | 496.69 | 594.21 |
| | 50 | .030 | 199.82 | 299.29 | 398.22 | 496.45 | 593.79 |
| 5 | | 100.032 | 199.81 | 299.24 | 398.10 | 496.20 | 593.36 |
| | 10 | .034 | 199.80 | 299.19 | 397.97 | 495.94 | 592.91 |
| | 20 | .036 | 199.78 | 299.13 | 397.84 | 495.68 | 592.45 |
| | 30 | .038 | 199.77 | 299.08 | 397.70 | 495.41 | 591.97 |
| | 40 | .041 | 199.76 | 299.02 | 397.56 | 495.12 | 591.48 |
| | 50 | .043 | 199.74 | 298.96 | 397.41 | 494.83 | 590.97 |
| 6 | | 100.046 | 199.73 | 298.90 | 397.26 | 494.53 | 590.45 |
| | 10 | .048 | 199.71 | 298.84 | 397.11 | 494.23 | 589.91 |
| | 20 | .051 | 199.70 | 298.78 | 396.95 | 493.91 | 589.36 |
| | 30 | .054 | 199.68 | 298.71 | 396.79 | 493.59 | 588.80 |
| | 40 | .056 | 199.66 | 298.65 | 396.62 | 493.26 | 588.22 |
| | 50 | .059 | 199.64 | 298.58 | 396.45 | 492.92 | 587.63 |
| 7 | | 100.062 | 199.63 | 298.51 | 396.28 | 492.57 | 587.02 |
| | 10 | .016 | 199.51 | 298.30 | 395.91 | 491.97 | 586.12 |
| | 20 | .017 | 199.49 | 298.21 | 395.71 | 491.60 | 585.46 |
| | 30 | .018 | 199.47 | 298.13 | 395.52 | 491.21 | 584.80 |
| | 40 | .018 | 199.44 | 298.05 | 395.32 | 490.82 | 584.13 |
| | 50 | .019 | 199.42 | 297.96 | 395.11 | 490.42 | 583.44 |
| 8 | | 100.020 | 199.39 | 297.87 | 394.90 | 490.01 | 582.72 |
| | 10 | .021 | 199.37 | 297.78 | 394.69 | 489.59 | 582.01 |
| | 20 | .022 | 199.34 | 297.69 | 394.47 | 489.16 | 581.27 |
| | 30 | .023 | 199.31 | 297.60 | 394.25 | 488.73 | 580.52 |
| | 40 | .024 | 199.28 | 297.50 | 394.02 | 488.28 | 579.76 |
| | 50 | .025 | 199.26 | 297.41 | 393.79 | 487.83 | 578.98 |
| 9 | | 100.026 | 199.23 | 297.31 | 393.55 | 487.37 | 578.18 |
| | 10 | .027 | 199.20 | 297.21 | 393.31 | 486.90 | 577.38 |
| | 20 | .028 | 199.17 | 297.10 | 393.07 | 486.43 | 576.56 |
| | 30 | .029 | 199.14 | 297.00 | 392.82 | 485.95 | 575.73 |
| | 40 | .030 | 199.11 | 296.90 | 392.57 | 485.45 | 574.88 |
| | 50 | .031 | 199.08 | 296.79 | 392.31 | 484.95 | 574.02 |
| 10 | | 100.032 | 199.05 | 296.68 | 392.05 | 484.44 | 573.14 |

## TABLE IV.—LONG CHORDS.

| Degree of Curve. | Actual Arc, One Station. | Long Chords. | | | | |
|---|---|---|---|---|---|---|
| | | 1 Station. | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. |
| 10° 0′ | 100.032 | 99.91 | 199.05 | 296.68 | 392.05 | 484.44 |
| 10 | .033 | 99.90 | 199.02 | 296.57 | 391.79 | 483.92 |
| 20 | .034 | 99.90 | 198.98 | 296.45 | 391.51 | 483.39 |
| 30 | .035 | 99.90 | 198.95 | 296.33 | 391.24 | 482.86 |
| 40 | .036 | 99.89 | 198.92 | 296.22 | 390.96 | 482.32 |
| 50 | .037 | 99.89 | 198.88 | 296.10 | 390.68 | 481.77 |
| 11 | 100.038 | 99.88 | 198.85 | 295.98 | 390.39 | 481.21 |
| 10 | .040 | 99.88 | 198.81 | 295.86 | 390.10 | 480.64 |
| 20 | .041 | 99.88 | 198.78 | 295.74 | 389.81 | 480.07 |
| 30 | .042 | 99.87 | 198.74 | 295.61 | 389.50 | 479.48 |
| 40 | .043 | 99.87 | 198.71 | 295.48 | 389.20 | 478.89 |
| 50 | .044 | 99.87 | 198.67 | 295.35 | 388.89 | 478.29 |
| 12 | 100.046 | 99.86 | 198.63 | 295.22 | 388.58 | 477.68 |
| 10 | .047 | 99.86 | 198.59 | 295.09 | 388.27 | 477.07 |
| 20 | .048 | 99.85 | 198.55 | 294.95 | 387.95 | 476.44 |
| 30 | .050 | 99.85 | 198.51 | 294.82 | 387.62 | 475.81 |
| 40 | .051 | 99.85 | 198.48 | 294.68 | 387.29 | 475.18 |
| 50 | .052 | 99.84 | 198.43 | 294.54 | 386.95 | 474.52 |
| 13 | 100.054 | 99.84 | 198.39 | 294.40 | 386.62 | 473.87 |
| 10 | .055 | 99.84 | 198.35 | 294.26 | 386.28 | 473.20 |
| 20 | .056 | 99.83 | 198.31 | 294.11 | 385.93 | 472.53 |
| 30 | .058 | 99.83 | 198.27 | 293.96 | 385.58 | 471.86 |
| 40 | .059 | 99.82 | 198.23 | 293.81 | 385.23 | 471.17 |
| 50 | .061 | 99.82 | 198.18 | 293.66 | 384.87 | 470.48 |
| 14 | 100.062 | 99.81 | 198.14 | 293.51 | 384.51 | 469.77 |

## TABLE V.—MID-ORDINATES TO LONG CHORDS.

| Degree of Curve. | 1 Station. | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
|---|---|---|---|---|---|---|
| 0° 10′ | .04 | .15 | .33 | .58 | .91 | 1.31 |
| 20 | .07 | .29 | .65 | 1.16 | 1.82 | 2.62 |
| 30 | .11 | .44 | .98 | 1.75 | 2.73 | 3.93 |
| 40 | .15 | .58 | 1.31 | 2.33 | 3.64 | 5.24 |
| 50 | .18 | .73 | 1.64 | 2.91 | 4.55 | 6.54 |
| 1 | .22 | .87 | 1.96 | 3.49 | 5.45 | 7.85 |
| 10 | .26 | 1.02 | 2.29 | 4.07 | 6.36 | 9.16 |
| 20 | .29 | 1.16 | 2.62 | 4.65 | 7.27 | 10.47 |
| 30 | .33 | 1.31 | 2.95 | 5.24 | 8.18 | 11.78 |
| 40 | .36 | 1.45 | 3.27 | 5.82 | 9.09 | 13.08 |
| 50 | .40 | 1.60 | 3.60 | 6.40 | 9.99 | 14.39 |
| 2 | .44 | 1.75 | 3.93 | 6.98 | 10.90 | 15.69 |
| 10 | .47 | 1.89 | 4.25 | 7.56 | 11.81 | 17.00 |
| 20 | .51 | 2.04 | 4.58 | 8.14 | 12.72 | 18.30 |
| 30 | .55 | 2.18 | 4.91 | 8.72 | 13.62 | 19.61 |
| 40 | .58 | 2.33 | 5.23 | 9.30 | 14.53 | 20.91 |
| 50 | .62 | 2.47 | 5.56 | 9.88 | 15.44 | 22.21 |
| 3 | .65 | 2.62 | 5.89 | 10.46 | 16.34 | 23.52 |
| 10 | .69 | 2.76 | 6.22 | 11.04 | 17.25 | 24.82 |
| 20 | .73 | 2.91 | 6.54 | 11.62 | 18.15 | 26.12 |
| 30 | .76 | 3.05 | 6.87 | 12.20 | 19.06 | 27.42 |
| 40 | .80 | 3.20 | 7.20 | 12.78 | 19.96 | 28.71 |
| 50 | .84 | 3.35 | 7.52 | 13.36 | 20.86 | 30.01 |
| 4 | .87 | 3.49 | 7.85 | 13.94 | 21.77 | 31.31 |

## TABLE V.—MID-ORDINATES TO LONG CHORDS.

| Degree of Curve. | 1 Station. | 2 Stations. | 3 Stations. | 4 Stations. | 5 Stations. | 6 Stations. |
|---|---|---|---|---|---|---|
| 4° 0′ | .87 | 3.49 | 7.85 | 13.94 | 21.77 | 31.31 |
| 10 | .91 | 3.64 | 8.18 | 14.52 | 22.67 | 32.60 |
| 20 | .95 | 3.78 | 8.50 | 15.10 | 23.57 | 33.90 |
| 30 | .98 | 3.93 | 8.83 | 15.68 | 24.47 | 35.19 |
| 40 | 1.02 | 4.07 | 9.15 | 16.26 | 25.37 | 36.48 |
| 50 | 1.05 | 4.22 | 9.48 | 16.84 | 26.27 | 37.77 |
| 5 | 1.09 | 4.36 | 9.81 | 17.42 | 27.17 | 39.06 |
| 10 | 1.13 | 4.51 | 10.13 | 17.99 | 28.07 | 40.35 |
| 20 | 1.16 | 4.65 | 10.46 | 18.57 | 28.97 | 41.63 |
| 30 | 1.20 | 4.80 | 10.79 | 19.15 | 29.87 | 42.92 |
| 40 | 1.24 | 4.94 | 11.11 | 19.72 | 30.76 | 44.20 |
| 50 | 1.27 | 5.09 | 11.44 | 20.30 | 31.66 | 45.48 |
| 6 | 1.31 | 5.23 | 11.76 | 20.88 | 32.55 | 46.76 |
| 10 | 1.35 | 5.38 | 12.09 | 21.45 | 33.45 | 48.04 |
| 20 | 1.38 | 5.52 | 12.41 | 22.03 | 34.34 | 49.31 |
| 30 | 1.42 | 5.67 | 12.74 | 22.60 | 35.23 | 50.59 |
| 40 | 1.46 | 5.81 | 13.06 | 23.18 | 36.13 | 51.86 |
| 50 | 1.49 | 5.96 | 13.39 | 23.75 | 37.02 | 53.13 |
| 7 | 1.53 | 6.11 | 13.72 | 24.33 | 37.91 | 54.40 |
| 10 | 1.56 | 6.25 | 14.03 | 24.89 | 38.79 | 55.64 |
| 20 | 1.60 | 6.39 | 14.36 | 25.46 | 39.66 | 56.90 |
| 30 | 1.64 | 6.54 | 14.68 | 26.04 | 40.55 | 58.16 |
| 40 | 1.67 | 6.68 | 15.01 | 26.61 | 41.43 | 59.41 |
| 50 | 1.71 | 6.83 | 15.33 | 27.18 | 42.32 | 60.68 |
| 8 | 1.74 | 6.97 | 15.65 | 27.75 | 43.20 | 61.93 |
| 10 | 1.78 | 7.12 | 15.98 | 28.32 | 44.08 | 63.18 |
| 20 | 1.82 | 7.26 | 16.30 | 28.89 | 44.96 | 64.43 |
| 30 | 1.85 | 7.41 | 16.62 | 29.46 | 45.84 | 65.68 |
| 40 | 1.89 | 7.55 | 16.95 | 30.03 | 46.72 | 66.92 |
| 50 | 1.93 | 7.70 | 17.27 | 30.60 | 47.60 | 68.17 |
| 9 | 1.96 | 7.84 | 17.59 | 31.17 | 48.47 | 69.40 |
| 10 | 2.00 | 7.98 | 17.92 | 31.73 | 49.35 | 70.64 |
| 20 | 2.04 | 8.13 | 18.24 | 32.30 | 50.22 | 71.88 |
| 30 | 2.07 | 8.27 | 18.56 | 32.87 | 51.09 | 73.11 |
| 40 | 2.11 | 8.42 | 18.88 | 33.43 | 51.96 | 74.34 |
| 50 | 2.14 | 8.56 | 19.21 | 34.00 | 52.83 | 75.56 |
| 10 | 2.18 | 8.71 | 19.53 | 34.56 | 53.70 | 76.79 |
| 10 | 2.22 | 8.85 | 19.85 | 35.13 | 54.57 | |
| 20 | 2.25 | 9.00 | 20.17 | 35.69 | 55.43 | |
| 30 | 2.29 | 9.14 | 20.49 | 36.26 | 56.29 | |
| 40 | 2.33 | 9.28 | 20.82 | 36.82 | 57.16 | |
| 50 | 2.36 | 9.43 | 21.14 | 37.38 | 58.02 | |
| 11 | 2.40 | 9.57 | 21.46 | 37.94 | 58.88 | |
| 10 | 2.44 | 9.72 | 21.78 | 38.50 | 59.73 | |
| 20 | 2.47 | 9.86 | 22.10 | 39.06 | 60.58 | |
| 30 | 2.51 | 10.01 | 22.42 | 39.62 | 61.44 | |
| 40 | 2.54 | 10.15 | 22.74 | 40.18 | 62.30 | |
| 50 | 2.58 | 10.29 | 23.06 | 40.74 | 63.15 | |
| 12 | 2.62 | 10.44 | 23.38 | 41.30 | 64.00 | |
| 10 | 2.65 | 10.58 | 23.70 | 41.86 | 64.85 | |
| 20 | 2.69 | 10.73 | 24.02 | 42.41 | 65.69 | |
| 30 | 2.73 | 10.87 | 24.34 | 42.97 | 66.54 | |
| 40 | 2.76 | 11.01 | 24.66 | 43.52 | 67.38 | |
| 50 | 2.80 | 11.16 | 24.97 | 44.08 | 68.22 | |
| 13 | 2.83 | 11.30 | 25.29 | 44.63 | 69.06 | |
| 10 | 2.87 | 11.45 | 25.61 | 45.18 | 69.90 | |
| 20 | 2.91 | 11.59 | 25.93 | 45.73 | 70.73 | |
| 30 | 2.94 | 11.73 | 26.25 | 46.29 | 71.57 | |
| 40 | 2.98 | 11.88 | 26.57 | 46.84 | 72.40 | |
| 50 | 3.02 | 12.02 | 26.88 | 47.39 | 73.23 | |
| 14 | 3.05 | 12.16 | 27.20 | 47.93 | 74.06 | |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **100** | 00000 | 00043 | 00087 | 00130 | 00173 | 00217 | 00260 | 00303 | 00346 | 00389 |
| **1** | 0432 | 0475 | 0518 | 0561 | 0604 | 0647 | 0689 | 0732 | 0775 | 0817 |
| **2** | 0860 | 0903 | 0945 | 0988 | 1030 | 1072 | 1115 | 1157 | 1199 | 1242 |
| **3** | 1284 | 1326 | 1368 | 1410 | 1452 | 1494 | 1536 | 1578 | 1620 | 1662 |
| **4** | 1703 | 1745 | 1787 | 1828 | 1870 | 1912 | 1953 | 1995 | 2036 | 2078 |
| **5** | 2119 | 2160 | 2202 | 2243 | 2284 | 2325 | 2366 | 2407 | 2449 | 2490 |
| **6** | 2531 | 2572 | 2612 | 2653 | 2694 | 2735 | 2776 | 2816 | 2857 | 2898 |
| **7** | 2938 | 2979 | 3019 | 3060 | 3100 | 3141 | 3181 | 3222 | 3262 | 3302 |
| **8** | 3342 | 3383 | 3423 | 3463 | 3503 | 3543 | 3583 | 3623 | 3663 | 3703 |
| **9** | 3743 | 3782 | 3822 | 3862 | 3902 | 3941 | 3981 | 4021 | 4060 | 4100 |
| **110** | 04139 | 04179 | 04218 | 04258 | 04297 | 04336 | 04376 | 04415 | 04454 | 04493 |
| **1** | 4532 | 4571 | 4610 | 4650 | 4689 | 4727 | 4766 | 4805 | 4844 | 4883 |
| **2** | 4922 | 4961 | 4999 | 5038 | 5077 | 5115 | 5154 | 5192 | 5231 | 5269 |
| **3** | 5308 | 5346 | 5385 | 5423 | 5461 | 5500 | 5538 | 5576 | 5614 | 5652 |
| **4** | 5690 | 5729 | 5767 | 5805 | 5843 | 5881 | 5918 | 5956 | 5994 | 6032 |
| **5** | 6070 | 6108 | 6145 | 6183 | 6221 | 6258 | 6296 | 6333 | 6371 | 6408 |
| **6** | 6446 | 6483 | 6521 | 6558 | 6595 | 6633 | 6670 | 6707 | 6744 | 6781 |
| **7** | 6819 | 6856 | 6893 | 6930 | 6967 | 7004 | 7041 | 7078 | 7115 | 7151 |
| **8** | 7188 | 7225 | 7262 | 7298 | 7335 | 7372 | 7408 | 7445 | 7482 | 7518 |
| **9** | 7555 | 7591 | 7628 | 7664 | 7700 | 7737 | 7773 | 7809 | 7846 | 7882 |
| **120** | 07918 | 07954 | 07990 | 08027 | 08063 | 08099 | 08135 | 08171 | 08207 | 08243 |
| **1** | 8279 | 8314 | 8350 | 8386 | 8422 | 8458 | 8493 | 8529 | 8565 | 8600 |
| **2** | 8636 | 8672 | 8707 | 8743 | 8778 | 8814 | 8849 | 8884 | 8920 | 8955 |
| **3** | 8991 | 9026 | 9061 | 9096 | 9132 | 9167 | 9202 | 9237 | 9272 | 9307 |
| **4** | 9342 | 9377 | 9412 | 9447 | 9482 | 9517 | 9552 | 9587 | 9621 | 9656 |
| **5** | 9691 | 9726 | 9760 | 9795 | 9830 | 9864 | 9899 | 9934 | 9968 | 10003 |
| **6** | 10037 | 10072 | 10106 | 10140 | 10175 | 10209 | 10243 | 10278 | 10312 | 0346 |
| **7** | 0380 | 0415 | 0449 | 0483 | 0517 | 0551 | 0585 | 0619 | 0653 | 0687 |
| **8** | 0721 | 0755 | 0789 | 0823 | 0857 | 0890 | 0924 | 0958 | 0992 | 1025 |
| **9** | 1059 | 1093 | 1126 | 1160 | 1193 | 1227 | 1261 | 1294 | 1327 | 1361 |
| **130** | 11394 | 11428 | 11461 | 11494 | 11528 | 11561 | 11594 | 11628 | 11661 | 11694 |
| **1** | 1727 | 1760 | 1793 | 1826 | 1860 | 1893 | 1926 | 1959 | 1992 | 2024 |
| **2** | 2057 | 2090 | 2123 | 2156 | 2189 | 2222 | 2254 | 2287 | 2320 | 2352 |
| **3** | 2385 | 2418 | 2450 | 2483 | 2516 | 2548 | 2581 | 2613 | 2646 | 2678 |
| **4** | 2710 | 2743 | 2775 | 2808 | 2840 | 2872 | 2905 | 2937 | 2969 | 3001 |
| **5** | 3033 | 3066 | 3098 | 3130 | 3162 | 3194 | 3226 | 3258 | 3290 | 3322 |
| **6** | 3354 | 3386 | 3418 | 3450 | 3481 | 3513 | 3545 | 3577 | 3609 | 3640 |
| **7** | 3672 | 3704 | 3735 | 3767 | 3799 | 3830 | 3862 | 3893 | 3925 | 3956 |
| **8** | 3988 | 4019 | 4051 | 4082 | 4114 | 4145 | 4176 | 4208 | 4239 | 4270 |
| **9** | 4301 | 4333 | 4364 | 4395 | 4426 | 4457 | 4489 | 4520 | 4551 | 4582 |
| **140** | 14613 | 14644 | 14675 | 14706 | 14737 | 14768 | 14799 | 14829 | 14860 | 14891 |
| **1** | 4922 | 4953 | 4983 | 5014 | 5045 | 5076 | 5106 | 5137 | 5168 | 5198 |
| **2** | 5229 | 5259 | 5290 | 5320 | 5351 | 5381 | 5412 | 5442 | 5473 | 5503 |
| **3** | 5534 | 5564 | 5594 | 5625 | 5655 | 5685 | 5715 | 5746 | 5776 | 5806 |
| **4** | 5836 | 5866 | 5897 | 5927 | 5957 | 5987 | 6017 | 6047 | 6077 | 6107 |
| **5** | 6137 | 6167 | 6197 | 6227 | 6256 | 6286 | 6316 | 6346 | 6376 | 6406 |
| **6** | 6435 | 6465 | 6495 | 6524 | 6554 | 6584 | 6613 | 6643 | 6673 | 6702 |
| **7** | 6732 | 6761 | 6791 | 6820 | 6850 | 6879 | 6909 | 6938 | 6967 | 6997 |
| **8** | 7026 | 7056 | 7085 | 7114 | 7143 | 7173 | 7202 | 7231 | 7260 | 7289 |
| **9** | 7319 | 7348 | 7377 | 7406 | 7435 | 7464 | 7493 | 7522 | 7551 | 7580 |
| **150** | 17609 | 17638 | 17667 | 17696 | 17725 | 17754 | 17782 | 17811 | 17840 | 17869 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **150** | 17609 | 17638 | 17667 | 17696 | 17725 | 17754 | 17782 | 17811 | 17840 | 17869 |
| **1** | 7898 | 7926 | 7955 | 7984 | 8013 | 8041 | 8070 | 8099 | 8127 | 8156 |
| **2** | 8184 | 8213 | 8241 | 8270 | 8298 | 8327 | 8355 | 8384 | 8412 | 8441 |
| **3** | 8469 | 8498 | 8526 | 8554 | 8583 | 8611 | 8639 | 8667 | 8696 | 8724 |
| **4** | 8752 | 8780 | 8808 | 8837 | 8865 | 8893 | 8921 | 8949 | 8977 | 9005 |
| **5** | 9033 | 9061 | 9089 | 9117 | 9145 | 9173 | 9201 | 9229 | 9257 | 9285 |
| **6** | 9312 | 9340 | 9368 | 9396 | 9424 | 9451 | 9479 | 9507 | 9535 | 9562 |
| **7** | 9590 | 9618 | 9645 | 9673 | 9700 | 9728 | 9756 | 9783 | 9811 | 9838 |
| **8** | 9866 | 9893 | 9921 | 9948 | 9976 | 20003 | 20030 | 20058 | 20085 | 20112 |
| **9** | 20140 | 20167 | 20194 | 20222 | 20249 | 0276 | 0303 | 0330 | 0358 | 0385 |
| **160** | 20412 | 20439 | 20466 | 20493 | 20520 | 20548 | 20575 | 20602 | 20629 | 20656 |
| **1** | 0683 | 0710 | 0737 | 0763 | 0790 | 0817 | 0844 | 0871 | 0898 | 0925 |
| **2** | 0952 | 0978 | 1005 | 1032 | 1059 | 1085 | 1112 | 1139 | 1165 | 1192 |
| **3** | 1219 | 1245 | 1272 | 1299 | 1325 | 1352 | 1378 | 1405 | 1431 | 1458 |
| **4** | 1484 | 1511 | 1537 | 1564 | 1590 | 1617 | 1643 | 1669 | 1696 | 1722 |
| **5** | 1748 | 1775 | 1801 | 1827 | 1854 | 1880 | 1906 | 1932 | 1958 | 1985 |
| **6** | 2011 | 2037 | 2063 | 2089 | 2115 | 2141 | 2167 | 2194 | 2220 | 2246 |
| **7** | 2272 | 2298 | 2324 | 2350 | 2376 | 2401 | 2427 | 2453 | 2479 | 2505 |
| **8** | 2531 | 2557 | 2583 | 2608 | 2634 | 2660 | 2686 | 2712 | 2737 | 2763 |
| **9** | 2789 | 2814 | 2840 | 2866 | 2891 | 2917 | 2943 | 2968 | 2994 | 3019 |
| **170** | 23045 | 23070 | 23096 | 23121 | 23147 | 23172 | 23198 | 23223 | 23249 | 23274 |
| **1** | 3300 | 3325 | 3350 | 3376 | 3401 | 3426 | 3452 | 3477 | 3502 | 3528 |
| **2** | 3553 | 3578 | 3603 | 3629 | 3654 | 3679 | 3704 | 3729 | 3754 | 3779 |
| **3** | 3805 | 3830 | 3855 | 3880 | 3905 | 3930 | 3955 | 3980 | 4005 | 4030 |
| **4** | 4055 | 4080 | 4105 | 4130 | 4155 | 4180 | 4204 | 4229 | 4254 | 4279 |
| **5** | 4304 | 4329 | 4353 | 4378 | 4403 | 4428 | 4452 | 4477 | 4502 | 4527 |
| **6** | 4551 | 4576 | 4601 | 4625 | 4650 | 4674 | 4699 | 4724 | 4748 | 4773 |
| **7** | 4797 | 4822 | 4846 | 4871 | 4895 | 4920 | 4944 | 4969 | 4993 | 5018 |
| **8** | 5042 | 5066 | 5091 | 5115 | 5139 | 5164 | 5188 | 5212 | 5237 | 5261 |
| **9** | 5285 | 5310 | 5334 | 5358 | 5382 | 5406 | 5431 | 5455 | 5479 | 5503 |
| **180** | 25527 | 25551 | 25575 | 25600 | 25624 | 25648 | 25672 | 25696 | 25720 | 25744 |
| **1** | 5768 | 5792 | 5816 | 5840 | 5864 | 5888 | 5912 | 5935 | 5959 | 5983 |
| **2** | 6007 | 6031 | 6055 | 6079 | 6102 | 6126 | 6150 | 6174 | 6198 | 6221 |
| **3** | 6245 | 6269 | 6293 | 6316 | 6340 | 6364 | 6387 | 6411 | 6435 | 6458 |
| **4** | 6482 | 6505 | 6529 | 6553 | 6576 | 6600 | 6623 | 6647 | 6670 | 6694 |
| **5** | 6717 | 6741 | 6764 | 6788 | 6811 | 6834 | 6858 | 6881 | 6905 | 6928 |
| **6** | 6951 | 6975 | 6998 | 7021 | 7045 | 7068 | 7091 | 7114 | 7138 | 7161 |
| **7** | 7184 | 7207 | 7231 | 7254 | 7277 | 7300 | 7323 | 7346 | 7370 | 7393 |
| **8** | 7416 | 7439 | 7462 | 7485 | 7508 | 7531 | 7554 | 7577 | 7600 | 7623 |
| **9** | 7646 | 7669 | 7692 | 7715 | 7738 | 7761 | 7784 | 7807 | 7830 | 7852 |
| **190** | 27875 | 27898 | 27921 | 27944 | 27967 | 27989 | 28012 | 28035 | 28058 | 28081 |
| **1** | 8103 | 8126 | 8149 | 8171 | 8194 | 8217 | 8240 | 8262 | 8285 | 8307 |
| **2** | 8330 | 8353 | 8375 | 8398 | 8421 | 8443 | 8466 | 8488 | 8511 | 8533 |
| **3** | 8556 | 8578 | 8601 | 8623 | 8646 | 8668 | 8691 | 8713 | 8735 | 8758 |
| **4** | 8780 | 8803 | 8825 | 8847 | 8870 | 8892 | 8914 | 8937 | 8959 | 8981 |
| **5** | 9003 | 9026 | 9048 | 9070 | 9092 | 9115 | 9137 | 9159 | 9181 | 9203 |
| **6** | 9226 | 9248 | 9270 | 9292 | 9314 | 9336 | 9358 | 9380 | 9403 | 9425 |
| **7** | 9447 | 9469 | 9491 | 9513 | 9535 | 9557 | 9579 | 9601 | 9623 | 9645 |
| **8** | 9667 | 9688 | 9710 | 9732 | 9754 | 9776 | 9798 | 9820 | 9842 | 9863 |
| **9** | 9885 | 9907 | 9929 | 9951 | 9973 | 9994 | 30016 | 30038 | 30060 | 30081 |
| **200** | 30103 | 30125 | 30146 | 30168 | 30190 | 30211 | 30233 | 30255 | 30276 | 30298 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **200** | 30103 | 30125 | 30146 | 30168 | 30190 | 30211 | 30233 | 30255 | 30276 | 30298 |
| **1** | 0320 | 0341 | 0363 | 0384 | 0406 | 0428 | 0449 | 0471 | 0492 | 0514 |
| **2** | 0535 | 0557 | 0578 | 0600 | 0621 | 0643 | 0664 | 0685 | 0707 | 0728 |
| **3** | 0750 | 0771 | 0792 | 0814 | 0835 | 0856 | 0878 | 0899 | 0920 | 0942 |
| **4** | 0963 | 0984 | 1006 | 1027 | 1048 | 1069 | 1091 | 1112 | 1133 | 1154 |
| **5** | 1175 | 1197 | 1218 | 1239 | 1260 | 1281 | 1302 | 1323 | 1345 | 1366 |
| **6** | 1387 | 1408 | 1429 | 1450 | 1471 | 1492 | 1513 | 1534 | 1555 | 1576 |
| **7** | 1597 | 1618 | 1639 | 1660 | 1681 | 1702 | 1723 | 1744 | 1765 | 1785 |
| **8** | 1806 | 1827 | 1848 | 1869 | 1890 | 1911 | 1931 | 1952 | 1973 | 1994 |
| **9** | 2015 | 2035 | 2056 | 2077 | 2098 | 2118 | 2139 | 2160 | 2181 | 2201 |
| **210** | 32222 | 32243 | 32263 | 32284 | 32305 | 32325 | 32346 | 32366 | 32387 | 32408 |
| **1** | 2428 | 2449 | 2469 | 2490 | 2510 | 2531 | 2552 | 2572 | 2593 | 2613 |
| **2** | 2634 | 2654 | 2675 | 2695 | 2715 | 2736 | 2756 | 2777 | 2797 | 2818 |
| **3** | 2838 | 2858 | 2879 | 2899 | 2919 | 2940 | 2960 | 2980 | 3001 | 3021 |
| **4** | 3041 | 3062 | 3082 | 3102 | 3122 | 3143 | 3163 | 3183 | 3203 | 3224 |
| **5** | 3244 | 3264 | 3284 | 3304 | 3325 | 3345 | 3365 | 3385 | 3405 | 3425 |
| **6** | 3445 | 3465 | 3486 | 3506 | 3526 | 3546 | 3566 | 3586 | 3606 | 3626 |
| **7** | 3646 | 3666 | 3686 | 3706 | 3726 | 3746 | 3766 | 3786 | 3806 | 3826 |
| **8** | 3846 | 3866 | 3885 | 3905 | 3925 | 3945 | 3965 | 3985 | 4005 | 4025 |
| **9** | 4044 | 4064 | 4084 | 4104 | 4124 | 4143 | 4163 | 4183 | 4203 | 4223 |
| **220** | 34242 | 34262 | 34282 | 34301 | 34321 | 34341 | 34361 | 34380 | 34400 | 34420 |
| **1** | 4439 | 4459 | 4479 | 4498 | 4518 | 4537 | 4557 | 4577 | 4596 | 4616 |
| **2** | 4635 | 4655 | 4674 | 4694 | 4713 | 4733 | 4753 | 4772 | 4792 | 4811 |
| **3** | 4830 | 4850 | 4869 | 4889 | 4908 | 4928 | 4947 | 4967 | 4986 | 5005 |
| **4** | 5025 | 5044 | 5064 | 5083 | 5102 | 5122 | 5141 | 5160 | 5180 | 5199 |
| **5** | 5218 | 5238 | 5257 | 5276 | 5295 | 5315 | 5334 | 5353 | 5372 | 5392 |
| **6** | 5411 | 5430 | 5449 | 5468 | 5488 | 5507 | 5526 | 5545 | 5564 | 5583 |
| **7** | 5603 | 5622 | 5641 | 5660 | 5679 | 5698 | 5717 | 5736 | 5755 | 5774 |
| **8** | 5793 | 5813 | 5832 | 5851 | 5870 | 5889 | 5908 | 5927 | 5946 | 5965 |
| **9** | 5984 | 6003 | 6021 | 6040 | 6059 | 6078 | 6097 | 6116 | 6135 | 6154 |
| **230** | 36173 | 36192 | 36211 | 36229 | 36248 | 36267 | 36286 | 36305 | 36324 | 36342 |
| **1** | 6361 | 6380 | 6399 | 6418 | 6436 | 6455 | 6474 | 6493 | 6511 | 6530 |
| **2** | 6549 | 6568 | 6586 | 6605 | 6624 | 6642 | 6661 | 6680 | 6698 | 6717 |
| **3** | 6736 | 6754 | 6773 | 6791 | 6810 | 6829 | 6847 | 6866 | 6884 | 6903 |
| **4** | 6922 | 6940 | 6959 | 6977 | 6996 | 7014 | 7033 | 7051 | 7070 | 7088 |
| **5** | 7107 | 7125 | 7144 | 7162 | 7181 | 7199 | 7218 | 7236 | 7254 | 7273 |
| **6** | 7291 | 7310 | 7328 | 7346 | 7365 | 7383 | 7401 | 7420 | 7438 | 7457 |
| **7** | 7475 | 7493 | 7511 | 7530 | 7548 | 7566 | 7585 | 7603 | 7621 | 7639 |
| **8** | 7658 | 7676 | 7694 | 7712 | 7731 | 7749 | 7767 | 7785 | 7803 | 7822 |
| **9** | 7840 | 7858 | 7876 | 7894 | 7912 | 7931 | 7949 | 7967 | 7985 | 8003 |
| **240** | 38021 | 38039 | 38057 | 38075 | 38093 | 38112 | 38130 | 38148 | 38166 | 38184 |
| **1** | 8202 | 8220 | 8238 | 8256 | 8274 | 8292 | 8310 | 8328 | 8346 | 8364 |
| **2** | 8382 | 8399 | 8417 | 8435 | 8453 | 8471 | 8489 | 8507 | 8525 | 8543 |
| **3** | 8561 | 8578 | 8596 | 8614 | 8632 | 8650 | 8668 | 8686 | 8703 | 8721 |
| **4** | 8739 | 8757 | 8775 | 8792 | 8810 | 8828 | 8846 | 8863 | 8881 | 8899 |
| **5** | 8917 | 8934 | 8952 | 8970 | 8987 | 9005 | 9023 | 9041 | 9058 | 9076 |
| **6** | 9094 | 9111 | 9129 | 9146 | 9164 | 9182 | 9199 | 9217 | 9235 | 9252 |
| **7** | 9270 | 9287 | 9305 | 9322 | 9340 | 9358 | 9375 | 9393 | 9410 | 9428 |
| **8** | 9445 | 9463 | 9480 | 9498 | 9515 | 9533 | 9550 | 9568 | 9585 | 9602 |
| **9** | 9620 | 9637 | 9655 | 9672 | 9690 | 9707 | 9724 | 9742 | 9759 | 9777 |
| **250** | 39794 | 39811 | 39829 | 39846 | 39863 | 39881 | 39898 | 39915 | 39933 | 39950 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **250** | 39794 | 39811 | 39829 | 39846 | 39863 | 39881 | 39898 | 39915 | 39933 | 39950 |
| **1** | 9967 | 99855̲ | 40002 | 40019 | 40037 | 40054 | 40071 | 40088 | 40106 | 40123 |
| **2** | 40140 | 40157 | 0175̲ | 0192 | 0209 | 0226 | 0243 | 0261 | 0278 | 0295̲ |
| **3** | 0312 | 0329 | 0346 | 0364 | 0381 | 0398 | 0415̲ | 0432 | 0449 | 0466 |
| **4** | 0483 | 0500 | 0518 | 0535̲ | 0552 | 0569 | 0586 | 0603 | 0620 | 0637 |
| **5** | 0654 | 0671 | 0688 | 0705 | 0722 | 0739 | 0756 | 0773 | 0790 | 0807 |
| **6** | 0824 | 0841 | 0858 | 0875̲ | 0892 | 0909 | 0926 | 0943 | 0960 | 0976 |
| **7** | 0993 | 1010 | 1027 | 1044 | 1061 | 1078 | 1095̲ | 1111 | 1128 | 1145 |
| **8** | 1162 | 1179 | 1196 | 1212 | 1229 | 1246 | 1263 | 1280 | 1296 | 1313 |
| **9** | 1330 | 1347 | 1363 | 1380 | 1397 | 1414 | 1430 | 1447 | 1464 | 1481 |
| **260** | 41497 | 41514 | 41531 | 41547 | 41564 | 41581 | 41597 | 41614 | 41631 | 41647 |
| **1** | 1664 | 1681 | 1697 | 1714 | 1731 | 1747 | 1764 | 1780 | 1797 | 1814 |
| **2** | 1830 | 1847 | 1863 | 1880 | 1896 | 1913 | 1929 | 1946 | 1963 | 1979 |
| **3** | 1996 | 2012 | 2029 | 2045 | 2062 | 2078 | 2095̲ | 2111 | 2127 | 2144 |
| **4** | 2160 | 2177 | 2193 | 2210 | 2226 | 2243 | 2259 | 2275 | 2292 | 2308 |
| **5** | 2325̲ | 2341 | 2357 | 2374 | 2390 | 2406 | 2423 | 2439 | 2455 | 2472 |
| **6** | 2488 | 2504 | 2521 | 2537 | 2553 | 2570 | 2586 | 2602 | 2619 | 2635̲ |
| **7** | 2651 | 2667 | 2684 | 2700 | 2716 | 2732 | 2749 | 2765̲ | 2781 | 2797 |
| **8** | 2813 | 2830 | 2846 | 2862 | 2878 | 2894 | 2911 | 2927 | 2943 | 2959 |
| **9** | 2975 | 2991 | 3008 | 3024 | 3040 | 3056 | 3072 | 3088 | 3104 | 3120 |
| **270** | 43136 | 43152 | 43169 | 43185̲ | 43201 | 43217 | 43233 | 43249 | 43265̲ | 43281 |
| **1** | 3297 | 3313 | 3329 | 3345̲ | 3361 | 3377 | 3393 | 3409 | 3425̲ | 3441 |
| **2** | 3457 | 3473 | 3489 | 3505̲ | 3521 | 3537 | 3553 | 3569 | 3584 | 3600 |
| **3** | 3616 | 3632 | 3648 | 3664 | 3680 | 3696 | 3712 | 3727 | 3743 | 3759 |
| **4** | 3775 | 3791 | 3807 | 3823 | 3838 | 3854 | 3870 | 3886 | 3902 | 3917 |
| **5** | 3933 | 3949 | 3965̲ | 3981 | 3996 | 4012 | 4028 | 4044 | 4059 | 4075 |
| **6** | 4091 | 4107 | 4122 | 4138 | 4154 | 4170 | 4185 | 4201 | 4217 | 4232 |
| **7** | 4248 | 4264 | 4279 | 4295̲ | 4311 | 4326 | 4342 | 4358 | 4373 | 4389 |
| **8** | 4404 | 4420 | 4436 | 4451 | 4467 | 4483 | 4498 | 4514 | 4529 | 4545̲ |
| **9** | 4560 | 4576 | 4592 | 4607 | 4623 | 4638 | 4654 | 4669 | 4685̲ | 4700 |
| **280** | 44716 | 44731 | 44747 | 44762 | 44778 | 44793 | 44809 | 44824 | 44840 | 44855 |
| **1** | 4871 | 4886 | 4902 | 4917 | 4932 | 4948 | 4963 | 4979 | 4994 | 5010 |
| **2** | 5025̲ | 5040 | 5056 | 5071 | 5086 | 5102 | 5117 | 5133 | 5148 | 5163 |
| **3** | 5179 | 5194 | 5209 | 5225̲ | 5240 | 5255 | 5271 | 5286 | 5301 | 5317 |
| **4** | 5332 | 5347 | 5362 | 5378 | 5393 | 5408 | 5423 | 5439 | 5454 | 5469 |
| **5** | 5484 | 55̲00 | 5515̲ | 5530 | 5545 | 5561 | 5576 | 5591 | 5606 | 5621 |
| **6** | 5637 | 5652 | 5667 | 5682 | 5697 | 5712 | 5728 | 5743 | 5758 | 5773 |
| **7** | 5788 | 5803 | 5818 | 5834 | 5849 | 5864 | 5879 | 5894 | 5909 | 5924 |
| **8** | 5939 | 5954 | 5969 | 5984 | 6000 | 6015̲ | 6030 | 6045̲ | 6060 | 6075̲ |
| **9** | 6090 | 6105̲ | 6120 | 6135̲ | 615̲0 | 6165̲ | 6180 | 6195̲ | 6210 | 6225̲ |
| **290** | 46240 | 46255̲ | 46270 | 46285̲ | 46300 | 46315̲ | 46330 | 46345̲ | 46359 | 46374 |
| **1** | 6389 | 6404 | 6419 | 6434 | 6449 | 6464 | 6479 | 6494 | 6509 | 6523 |
| **2** | 6538 | 6553 | 6568 | 6583 | 6598 | 6613 | 6627 | 6642 | 6657 | 6672 |
| **3** | 6687 | 6702 | 6716 | 6731 | 6746 | 6761 | 6776 | 6790 | 6805 | 6820 |
| **4** | 6835̲ | 685̲0 | 6864 | 6879 | 6894 | 6909 | 6923 | 6938 | 6953 | 6967 |
| **5** | 6982 | 6997 | 7012 | 7026 | 7041 | 7056 | 7070 | 7085 | 7100 | 7114 |
| **6** | 7129 | 7144 | 7159 | 7173 | 7188 | 7202 | 7217 | 7232 | 7246 | 7261 |
| **7** | 7276 | 7290 | 7305̲ | 7319 | 7334 | 7349 | 7363 | 7378 | 7392 | 7407 |
| **8** | 7422 | 7436 | 7451 | 7465 | 7480 | 7494 | 7509 | 7524 | 7538 | 7553 |
| **9** | 7567 | 7582 | 7596 | 7611 | 7625 | 7640 | 7654 | 7669 | 7683 | 7698 |
| **300** | 47712 | 47727 | 47741 | 47756 | 47770 | 47784 | 47799 | 47813 | 47828 | 47842 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **300** | 47712 | 47727 | 47741 | 47756 | 47770 | 47784 | 47799 | 47813 | 47828 | 47842 |
| **1** | 7857 | 7871 | 7885 | 7900 | 7914 | 7929 | 7943 | 7958 | 7972 | 7986 |
| **2** | 8001 | 8015 | 8029 | 8044 | 8058 | 8073 | 8087 | 8101 | 8116 | 8130 |
| **3** | 8144 | 8159 | 8173 | 8187 | 8202 | 8216 | 8230 | 8244 | 8259 | 8273 |
| **4** | 8287 | 8302 | 8316 | 8330 | 8344 | 8359 | 8373 | 8387 | 8401 | 8416 |
| **5** | 8430 | 8444 | 8458 | 8473 | 8487 | 8501 | 8515 | 8530 | 8544 | 8558 |
| **6** | 8572 | 8586 | 8601 | 8615 | 8629 | 8643 | 8657 | 8671 | 8686 | 8700 |
| **7** | 8714 | 8728 | 8742 | 8756 | 8770 | 8785 | 8799 | 8813 | 8827 | 8841 |
| **8** | 8855 | 8869 | 8883 | 8897 | 8911 | 8926 | 8940 | 8954 | 8968 | 8982 |
| **9** | 8996 | 9010 | 9024 | 9038 | 9052 | 9066 | 9080 | 9094 | 9108 | 9122 |
| **310** | 49136 | 49150 | 49164 | 49178 | 49192 | 49206 | 49220 | 49234 | 49248 | 49262 |
| **1** | 9276 | 9290 | 9304 | 9318 | 9332 | 9346 | 9360 | 9374 | 9388 | 9402 |
| **2** | 9415 | 9429 | 9443 | 9457 | 9471 | 9485 | 9499 | 9513 | 9527 | 9541 |
| **3** | 9554 | 9568 | 9582 | 9596 | 9610 | 9624 | 9638 | 9651 | 9665 | 9679 |
| **4** | 9693 | 9707 | 9721 | 9734 | 9748 | 9762 | 9776 | 9790 | 9803 | 9817 |
| **5** | 9831 | 9845 | 9859 | 9872 | 9886 | 9900 | 9914 | 9927 | 9941 | 9955 |
| **6** | 9969 | 9982 | 9996 | 50010 | 50024 | 50037 | 50051 | 50065 | 50079 | 50092 |
| **7** | 50106 | 50120 | 50133 | 0147 | 0161 | 0174 | 0188 | 0202 | 0215 | 0229 |
| **8** | 0243 | 0256 | 0270 | 0284 | 0297 | 0311 | 0325 | 0338 | 0352 | 0365 |
| **9** | 0379 | 0393 | 0406 | 0420 | 0433 | 0447 | 0461 | 0474 | 0488 | 0501 |
| **320** | 50515 | 50529 | 50542 | 50556 | 50569 | 50583 | 50596 | 50610 | 50623 | 50637 |
| **1** | 0651 | 0664 | 0678 | 0691 | 0705 | 0718 | 0732 | 0745 | 0759 | 0772 |
| **2** | 0786 | 0799 | 0813 | 0826 | 0840 | 0853 | 0866 | 0880 | 0893 | 0907 |
| **3** | 0920 | 0934 | 0947 | 0961 | 0974 | 0987 | 1001 | 1014 | 1028 | 1041 |
| **4** | 1055 | 1068 | 1081 | 1095 | 1108 | 1121 | 1135 | 1148 | 1162 | 1175 |
| **5** | 1188 | 1202 | 1215 | 1228 | 1242 | 1255 | 1268 | 1282 | 1295 | 1308 |
| **6** | 1322 | 1335 | 1348 | 1362 | 1375 | 1388 | 1402 | 1415 | 1428 | 1441 |
| **7** | 1455 | 1468 | 1481 | 1495 | 1508 | 1521 | 1534 | 1548 | 1561 | 1574 |
| **8** | 1587 | 1601 | 1614 | 1627 | 1640 | 1654 | 1667 | 1680 | 1693 | 1706 |
| **9** | 1720 | 1733 | 1746 | 1759 | 1772 | 1786 | 1799 | 1812 | 1825 | 1838 |
| **330** | 51851 | 51865 | 51878 | 51891 | 51904 | 51917 | 51930 | 51943 | 51957 | 51970 |
| **1** | 1983 | 1996 | 2009 | 2022 | 2035 | 2048 | 2061 | 2075 | 2088 | 2101 |
| **2** | 2114 | 2127 | 2140 | 2153 | 2166 | 2179 | 2192 | 2205 | 2218 | 2231 |
| **3** | 2244 | 2257 | 2270 | 2284 | 2297 | 2310 | 2323 | 2336 | 2349 | 2362 |
| **4** | 2375 | 2388 | 2401 | 2414 | 2427 | 2440 | 2453 | 2466 | 2479 | 2492 |
| **5** | 2504 | 2517 | 2530 | 2543 | 2556 | 2569 | 2582 | 2595 | 2608 | 2621 |
| **6** | 2634 | 2647 | 2660 | 2673 | 2686 | 2699 | 2711 | 2724 | 2737 | 2750 |
| **7** | 2763 | 2776 | 2789 | 2802 | 2815 | 2827 | 2840 | 2853 | 2866 | 2879 |
| **8** | 2892 | 2905 | 2917 | 2930 | 2943 | 2956 | 2969 | 2982 | 2994 | 3007 |
| **9** | 3020 | 3033 | 3046 | 3058 | 3071 | 3084 | 3097 | 3110 | 3122 | 3135 |
| **340** | 53148 | 53161 | 53173 | 53186 | 53199 | 53212 | 53224 | 53237 | 53250 | 53263 |
| **1** | 3275 | 3288 | 3301 | 3314 | 3326 | 3339 | 3352 | 3364 | 3377 | 3390 |
| **2** | 3403 | 3415 | 3428 | 3441 | 3453 | 3466 | 3479 | 3491 | 3504 | 3517 |
| **3** | 3529 | 3542 | 3555 | 3567 | 3580 | 3593 | 3605 | 3618 | 3631 | 3643 |
| **4** | 3656 | 3668 | 3681 | 3694 | 3706 | 3719 | 3732 | 3744 | 3757 | 3769 |
| **5** | 3782 | 3794 | 3807 | 3820 | 3832 | 3845 | 3857 | 3870 | 3882 | 3895 |
| **6** | 3908 | 3920 | 3933 | 3945 | 3958 | 3970 | 3983 | 3995 | 4008 | 4020 |
| **7** | 4033 | 4045 | 4058 | 4070 | 4083 | 4095 | 4108 | 4120 | 4133 | 4145 |
| **8** | 4158 | 4170 | 4183 | 4195 | 4208 | 4220 | 4233 | 4245 | 4258 | 4270 |
| **9** | 4283 | 4295 | 4307 | 4320 | 4332 | 4345 | 4357 | 4370 | 4382 | 4394 |
| **350** | 54407 | 54419 | 54432 | 54444 | 54456 | 54469 | 54481 | 54494 | 54506 | 54518 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 350 | 54407 | 54419 | 54432 | 54444 | 54456 | 54469 | 54481 | 54494 | 54506 | 54518 |
| 1 | 4531 | 4543 | 4555 | 4568 | 4580 | 4593 | 4605 | 4617 | 4630 | 4642 |
| 2 | 4654 | 4667 | 4679 | 4691 | 4704 | 4716 | 4728 | 4741 | 4753 | 4765 |
| 3 | 4777 | 4790 | 4802 | 4814 | 4827 | 4839 | 4851 | 4864 | 4876 | 4888 |
| 4 | 4900 | 4913 | 4925 | 4937 | 4949 | 4962 | 4974 | 4986 | 4998 | 5011 |
| 5 | 5023 | 5035 | 5047 | 5060 | 5072 | 5084 | 5096 | 5108 | 5121 | 5133 |
| 6 | 5145 | 5157 | 5169 | 5182 | 5194 | 5206 | 5218 | 5230 | 5242 | 5255 |
| 7 | 5267 | 5279 | 5291 | 5303 | 5315 | 5328 | 5340 | 5352 | 5364 | 5376 |
| 8 | 5388 | 5400 | 5413 | 5425 | 5437 | 5449 | 5461 | 5473 | 5485 | 5497 |
| 9 | 5509 | 5522 | 5534 | 5546 | 5558 | 5570 | 5582 | 5594 | 5606 | 5618 |
| 360 | 55630 | 55642 | 55654 | 55666 | 55678 | 55691 | 55703 | 55715 | 55727 | 55739 |
| 1 | 5751 | 5763 | 5775 | 5787 | 5799 | 5811 | 5823 | 5835 | 5847 | 5859 |
| 2 | 5871 | 5883 | 5895 | 5907 | 5919 | 5931 | 5943 | 5955 | 5967 | 5979 |
| 3 | 5991 | 6003 | 6015 | 6027 | 6038 | 6050 | 6062 | 6074 | 6086 | 6098 |
| 4 | 6110 | 6122 | 6134 | 6146 | 6158 | 6170 | 6182 | 6194 | 6205 | 6217 |
| 5 | 6229 | 6241 | 6253 | 6265 | 6277 | 6289 | 6301 | 6312 | 6324 | 6336 |
| 6 | 6348 | 6360 | 6372 | 6384 | 6396 | 6407 | 6419 | 6431 | 6443 | 6455 |
| 7 | 6467 | 6478 | 6490 | 6502 | 6514 | 6526 | 6538 | 6549 | 6561 | 6573 |
| 8 | 6585 | 6597 | 6608 | 6620 | 6632 | 6644 | 6656 | 6667 | 6679 | 6691 |
| 9 | 6703 | 6714 | 6726 | 6738 | 6750 | 6761 | 6773 | 6785 | 6797 | 6808 |
| 370 | 56820 | 56832 | 56844 | 56855 | 56867 | 56879 | 56891 | 56902 | 56914 | 56926 |
| 1 | 6937 | 6949 | 6961 | 6972 | 6984 | 6996 | 7008 | 7019 | 7031 | 7043 |
| 2 | 7054 | 7066 | 7078 | 7089 | 7101 | 7113 | 7124 | 7136 | 7148 | 7159 |
| 3 | 7171 | 7183 | 7194 | 7206 | 7217 | 7229 | 7241 | 7252 | 7264 | 7276 |
| 4 | 7287 | 7299 | 7310 | 7322 | 7334 | 7345 | 7357 | 7368 | 7380 | 7392 |
| 5 | 7403 | 7415 | 7426 | 7438 | 7449 | 7461 | 7473 | 7484 | 7496 | 7507 |
| 6 | 7519 | 7530 | 7542 | 7553 | 7565 | 7576 | 7588 | 7600 | 7611 | 7623 |
| 7 | 7634 | 7646 | 7657 | 7669 | 7680 | 7692 | 7703 | 7715 | 7726 | 7738 |
| 8 | 7749 | 7761 | 7772 | 7784 | 7795 | 7807 | 7818 | 7830 | 7841 | 7852 |
| 9 | 7864 | 7875 | 7887 | 7898 | 7910 | 7921 | 7933 | 7944 | 7955 | 7967 |
| 380 | 57978 | 57990 | 58001 | 58013 | 58024 | 58035 | 58047 | 58058 | 58070 | 58081 |
| 1 | 8092 | 8104 | 8115 | 8127 | 8138 | 8149 | 8161 | 8172 | 8184 | 8195 |
| 2 | 8206 | 8218 | 8229 | 8240 | 8252 | 8263 | 8274 | 8286 | 8297 | 8309 |
| 3 | 8320 | 8331 | 8343 | 8354 | 8365 | 8377 | 8388 | 8399 | 8410 | 8422 |
| 4 | 8433 | 8444 | 8456 | 8467 | 8478 | 8490 | 8501 | 8512 | 8524 | 8535 |
| 5 | 8546 | 8557 | 8569 | 8580 | 8591 | 8602 | 8614 | 8625 | 8636 | 8647 |
| 6 | 8659 | 8670 | 8681 | 8692 | 8704 | 8715 | 8726 | 8737 | 8749 | 8760 |
| 7 | 8771 | 8782 | 8794 | 8805 | 8816 | 8827 | 8838 | 8850 | 8861 | 8872 |
| 8 | 8883 | 8894 | 8906 | 8917 | 8928 | 8939 | 8950 | 8961 | 8973 | 8984 |
| 9 | 8995 | 9006 | 9017 | 9028 | 9040 | 9051 | 9062 | 9073 | 9084 | 9095 |
| 390 | 59106 | 59118 | 59129 | 59140 | 59151 | 59162 | 59173 | 59184 | 59195 | 59207 |
| 1 | 9218 | 9229 | 9240 | 9251 | 9262 | 9273 | 9284 | 9295 | 9306 | 9318 |
| 2 | 9329 | 9340 | 9351 | 9362 | 9373 | 9384 | 9395 | 9406 | 9417 | 9428 |
| 3 | 9439 | 9450 | 9461 | 9472 | 9483 | 9494 | 9506 | 9517 | 9528 | 9539 |
| 4 | 9550 | 9561 | 9572 | 9583 | 9594 | 9605 | 9616 | 9627 | 9638 | 9649 |
| 5 | 9660 | 9671 | 9682 | 9693 | 9704 | 9715 | 9726 | 9737 | 9748 | 9759 |
| 6 | 9770 | 9780 | 9791 | 9802 | 9813 | 9824 | 9835 | 9846 | 9857 | 9868 |
| 7 | 9879 | 9890 | 9901 | 9912 | 9923 | 9934 | 9945 | 9956 | 9966 | 9977 |
| 8 | 9988 | 9999 | 60010 | 60021 | 60032 | 60043 | 60054 | 60065 | 60076 | 60086 |
| 9 | 60097 | 60108 | 0119 | 0130 | 0141 | 0152 | 0163 | 0173 | 0184 | 0195 |
| 400 | 60206 | 60217 | 60228 | 60239 | 60249 | 60260 | 60271 | 60282 | 60293 | 60304 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **400** | 60206 | 60217 | 60228 | 60239 | 60249 | 60260 | 60271 | 60282 | 60293 | 60304 |
| **1** | 0314 | 0325 | 0336 | 0347 | 0358 | 0369 | 0379 | 0390 | 0401 | 0412 |
| **2** | 0423 | 0433 | 0444 | 0455 | 0466 | 0477 | 0487 | 0498 | 0509 | 0520 |
| **3** | 0531 | 0541 | 0552 | 0563 | 0574 | 0584 | 0595 | 0606 | 0617 | 0627 |
| **4** | 0638 | 0649 | 0660 | 0670 | 0681 | 0692 | 0703 | 0713 | 0724 | 073$\underline{5}$ |
| **5** | 0746 | 0756 | 0767 | 0778 | 0788 | 0799 | 0810 | 0821 | 0831 | 0842 |
| **6** | 0853 | 0863 | 0874 | 088$\underline{5}$ | 0895 | 0906 | 0917 | 0927 | 0938 | 0949 |
| **7** | 0959 | 0970 | 0981 | 0991 | 1002 | 1013 | 1023 | 1034 | 104$\underline{5}$ | 1055 |
| **8** | 1066 | 1077 | 1087 | 1098 | 1109 | 1119 | 1130 | 1140 | 1151 | 1162 |
| **9** | 1172 | 1183 | 1194 | 1204 | 121$\underline{5}$ | 1225 | 1236 | 1247 | 1257 | 1268 |
| **410** | 61278 | 61289 | 61300 | 61310 | 61321 | 61331 | 61342 | 61352 | 61363 | 61374 |
| **1** | 1384 | 139$\underline{5}$ | 1405 | 1416 | 1426 | 1437 | 1448 | 1458 | 1469 | 1479 |
| **2** | 1490 | 1500 | 1511 | 1521 | 1532 | 1542 | 1553 | 1563 | 1574 | 1584 |
| **3** | 1595 | 1606 | 1616 | 1627 | 1637 | 1648 | 1658 | 1669 | 1679 | 1690 |
| **4** | 1700 | 1711 | 1721 | 1731 | 1742 | 1752 | 1763 | 1773 | 1784 | 1794 |
| **5** | 180$\underline{5}$ | 1815 | 1826 | 1836 | 1847 | 1857 | 1868 | 1878 | 1888 | 1899 |
| **6** | 1909 | 1920 | 1930 | 1941 | 1951 | 1962 | 1972 | 1982 | 1993 | 2003 |
| **7** | 2014 | 2024 | 2034 | 204$\underline{5}$ | 2055 | 2066 | 2076 | 2086 | 2097 | 2107 |
| **8** | 2118 | 2128 | 2138 | 2149 | 2159 | 2170 | 2180 | 2190 | 2201 | 2211 |
| **9** | 2221 | 2232 | 2242 | 2252 | 2263 | 2273 | 2284 | 2294 | 2304 | 231$\underline{5}$ |
| **420** | 6232$\underline{5}$ | 62335 | 62346 | 62356 | 62366 | 62377 | 62387 | 62397 | 62408 | 62418 |
| **1** | 2428 | 2439 | 2449 | 2459 | 2469 | 2480 | 2490 | 2500 | 2511 | 2521 |
| **2** | 2531 | 2542 | 2552 | 2562 | 2572 | 2583 | 2593 | 2603 | 2613 | 2624 |
| **3** | 2634 | 2644 | 265$\underline{5}$ | 266$\underline{5}$ | 2675 | 2685 | 2696 | 2706 | 2716 | 2726 |
| **4** | 2737 | 2747 | 2757 | 2767 | 2778 | 2788 | 2798 | 2808 | 2818 | 2829 |
| **5** | 2839 | 2849 | 2859 | 2870 | 2880 | 2890 | 2900 | 2910 | 2921 | 2931 |
| **6** | 2941 | 2951 | 2961 | 2972 | 2982 | 2992 | 3002 | 3012 | 3022 | 3033 |
| **7** | 3043 | 3053 | 3063 | 3073 | 3083 | 3094 | 3104 | 3114 | 3124 | 3134 |
| **8** | 3144 | 315$\underline{5}$ | 316$\underline{5}$ | 317$\underline{5}$ | 318$\underline{5}$ | 3195 | 3205 | 3215 | 3225 | 3236 |
| **9** | 3246 | 3256 | 3266 | 3276 | 3286 | 3296 | 3306 | 3317 | 3327 | 3337 |
| **430** | 63347 | 63357 | 63367 | 63377 | 63387 | 63397 | 63407 | 63417 | 63428 | 63438 |
| **1** | 3448 | 3458 | 3468 | 3478 | 3488 | 3498 | 3508 | 3518 | 3528 | 3538 |
| **2** | 3548 | 3558 | 3568 | 3579 | 3589 | 3599 | 3609 | 3619 | 3629 | 3639 |
| **3** | 3649 | 3659 | 3669 | 3679 | 3689 | 3699 | 3709 | 3719 | 3729 | 3739 |
| **4** | 3749 | 3759 | 3769 | 3779 | 3789 | 3799 | 3809 | 3819 | 3829 | 3839 |
| **5** | 3849 | 3859 | 3869 | 3879 | 3889 | 3899 | 3909 | 3919 | 3929 | 3939 |
| **6** | 3949 | 3959 | 3969 | 3979 | 3988 | 3998 | 4008 | 4018 | 4028 | 4038 |
| **7** | 4048 | 4058 | 4068 | 4078 | 4088 | 4098 | 4108 | 4118 | 4128 | 4137 |
| **8** | 4147 | 4157 | 4167 | 4177 | 4187 | 4197 | 4207 | 4217 | 4227 | 4237 |
| **9** | 4246 | 4256 | 4266 | 4276 | 4286 | 4296 | 4306 | 4316 | 4326 | 4335 |
| **440** | 64345 | 64355 | 64365 | 6437$\underline{5}$ | 6438$\underline{5}$ | 6439$\underline{5}$ | 64404 | 64414 | 64424 | 64434 |
| **1** | 4444 | 4454 | 4464 | 4473 | 4483 | 4493 | 4503 | 4513 | 4523 | 4532 |
| **2** | 4542 | 4552 | 4562 | 4572 | 4582 | 4591 | 4601 | 4611 | 4621 | 4631 |
| **3** | 4640 | 4650 | 4660 | 4670 | 4680 | 4689 | 4699 | 4709 | 4719 | 4729 |
| **4** | 4738 | 4748 | 4758 | 4768 | 4777 | 4787 | 4797 | 4807 | 4816 | 4826 |
| **5** | 4836 | 4846 | 4856 | 4865 | 4875 | 4885 | 4895 | 4904 | 4914 | 4924 |
| **6** | 4933 | 4943 | 4953 | 4963 | 4972 | 4982 | 4992 | 5002 | 5011 | 5021 |
| **7** | 5031 | 5040 | 5050 | 5060 | 5070 | 5079 | 5089 | 5099 | 5108 | 5118 |
| **8** | 5128 | 5137 | 5147 | 5157 | 5167 | 5176 | 5186 | 5196 | 5205 | 521$\underline{5}$ |
| **9** | 522$\underline{5}$ | 5234 | 5244 | 5254 | 5263 | 5273 | 5283 | 5292 | 5302 | 5312 |
| **450** | 65321 | 65331 | 65341 | 65350 | 65360 | 65369 | 65379 | 65389 | 65398 | 65408 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **450** | 65321 | 65331 | 65341 | 65350 | 65360 | 65369 | 65379 | 65389 | 65398 | 65408 |
| **1** | 5418 | 5427 | 5437 | 5447 | 5456 | 5466 | 5475 | 5485 | 5495̲ | 5504 |
| **2** | 5514 | 5523 | 5533 | 5543 | 5552 | 5562 | 5571 | 5581 | 5591 | 5600 |
| **3** | 5610 | 5619 | 5629 | 5639 | 5648 | 5658 | 5667 | 5677 | 5686 | 5696 |
| **4** | 5706 | 5715 | 5725̲ | 5734 | 5744 | 5753 | 5763 | 5772 | 5782 | 5792 |
| **5** | 5801 | 5811 | 5820 | 5830 | 5839 | 5849 | 5858 | 5868 | 5877 | 5887 |
| **6** | 5896 | 5906 | 5916 | 5925 | 5935̲ | 5944 | 5954 | 5963 | 5973 | 5982 |
| **7** | 5992 | 6001 | 6011 | 6020 | 6030 | 6039 | 6049 | 6058 | 6068 | 6077 |
| **8** | 6087 | 6096 | 6106 | 6115̲ | 6124 | 6134 | 6143 | 6153 | 6162 | 6172 |
| **9** | 6181 | 6191 | 6200 | 6210 | 6219 | 6229 | 6238 | 6247 | 6257 | 6266 |
| **460** | 66276 | 66285 | 66295̲ | 66304 | 66314 | 66323 | 66332 | 66342 | 66351 | 66361 |
| **1** | 6370 | 6380 | 6389 | 6398 | 6408 | 6417 | 6427 | 6436 | 6445 | 6455̲ |
| **2** | 6464 | 6474 | 6483 | 6492 | 6502 | 6511 | 6521 | 6530 | 6539 | 6549 |
| **3** | 6558 | 6567 | 6577 | 6586 | 6596 | 6605̲ | 6614 | 6624 | 6633 | 6642 |
| **4** | 6652 | 6661 | 6671 | 6680 | 6689 | 6699 | 6708 | 6717 | 6727 | 6736 |
| **5** | 6745 | 6755̲ | 6764 | 6773 | 6783 | 6792 | 6801 | 6811 | 6820 | 6829 |
| **6** | 6839 | 6848 | 6857 | 6867 | 6876 | 6885 | 6894 | 6904 | 6913 | 6922 |
| **7** | 6932 | 6941 | 6950 | 6960 | 6969 | 6978 | 6987 | 6997 | 7006 | 7015 |
| **8** | 7025̲ | 7034 | 7043 | 7052 | 7062 | 7071 | 7080 | 7089 | 7099 | 7108 |
| **9** | 7117 | 7127 | 7136 | 7145 | 7154 | 7164 | 7173 | 7182 | 7191 | 7201 |
| **470** | 67210 | 67219 | 67228 | 67237 | 67247 | 67256 | 67265 | 67274 | 67284 | 67293 |
| **1** | 7302 | 7311 | 7321 | 7330 | 7339 | 7348 | 7357 | 7367 | 7376 | 7385̲ |
| **2** | 7394 | 7403 | 7413 | 7422 | 7431 | 7440 | 7449 | 7459 | 7468 | 7477 |
| **3** | 7486 | 7495 | 7504 | 7514 | 7523 | 7532 | 7541 | 7550 | 7560 | 7569 |
| **4** | 7578 | 7587 | 7596 | 7605 | 7614 | 7624 | 7633 | 7642 | 7651 | 7660 |
| **5** | 7669 | 7679 | 7688 | 7697 | 7706 | 7715 | 7724 | 7733 | 7742 | 7752 |
| **6** | 7761 | 7770 | 7779 | 7788 | 7797 | 7806 | 7815 | 7825̲ | 7834 | 7843 |
| **7** | 7852 | 7861 | 7870 | 7879 | 7888 | 7897 | 7906 | 7916 | 7925̲ | 7934 |
| **8** | 7943 | 7952 | 7961 | 7970 | 7979 | 7988 | 7997 | 8006 | 8015 | 8024 |
| **9** | 8034 | 8043 | 8052 | 8061 | 8070 | 8079 | 8088 | 8097 | 8106 | 8115 |
| **480** | 68124 | 68133 | 68142 | 68151 | 68160 | 68169 | 68178 | 68187 | 68196 | 68205 |
| **1** | 8215̲ | 8224 | 8233 | 8242 | 8251 | 8260 | 8269 | 8278 | 8287 | 8296 |
| **2** | 8305̲ | 8314 | 8323 | 8332 | 8341 | 835̲0 | 8359 | 8368 | 8377 | 8386 |
| **3** | 8395̲ | 8404 | 8413 | 8422 | 8431 | 8440 | 8449 | 8458 | 8467 | 8476 |
| **4** | 8485̲ | 8494 | 8502 | 8511 | 8520 | 8529 | 8538 | 8547 | 8556 | 8565 |
| **5** | 8574 | 8583 | 8592 | 8601 | 8610 | 8619 | 8628 | 8637 | 8646 | 8655̲ |
| **6** | 8664 | 8673 | 8681 | 8690 | 8699 | 8708 | 8717 | 8726 | 8735 | 8744 |
| **7** | 8753 | 8762 | 8771 | 8780 | 8789 | 8797 | 8806 | 8815 | 8824 | 8833 |
| **8** | 8842 | 8851 | 8860 | 8869 | 8878 | 8886 | 8895 | 8904 | 8913 | 8922 |
| **9** | 8931 | 8940 | 8949 | 8958 | 8966 | 8975 | 8984 | 8993 | 9002 | 9011 |
| **490** | 69020 | 69028 | 69037 | 69046 | 69055 | 69064 | 69073 | 69082 | 69090 | 69099 |
| **1** | 9108 | 9117 | 9126 | 9135̲ | 9144 | 9152 | 9161 | 9170 | 9179 | 9188 |
| **2** | 9197 | 9205 | 9214 | 9223 | 9232 | 9241 | 9249 | 9258 | 9267 | 9276 |
| **3** | 9285̲ | 9294 | 9302 | 9311 | 9320 | 9329 | 9338 | 9346 | 9355 | 9364 |
| **4** | 9373 | 9381 | 9390 | 9399 | 9408 | 9417 | 9425 | 9434 | 9443 | 9452 |
| **5** | 9461 | 9469 | 9478 | 9487 | 9496 | 9504 | 9513 | 9522 | 9531 | 9539 |
| **6** | 9548 | 9557 | 9566 | 9574 | 9583 | 9592 | 9601 | 9609 | 9618 | 9627 |
| **7** | 9636 | 9644 | 9653 | 9662 | 9671 | 9679 | 9688 | 9697 | 9705 | 9714 |
| **8** | 9723 | 9732 | 9740 | 9749 | 9758 | 9767 | 9775 | 9784 | 9793 | 9801 |
| **9** | 9810 | 9819 | 9827 | 9836 | 9845̲ | 9854 | 9862 | 9871 | 9880 | 9888 |
| **500** | 69897 | 69906 | 69914 | 69923 | 69932 | 69940 | 69949 | 69958 | 69966 | 69975 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **500** | 69897 | 69906 | 69914 | 69923 | 69932 | 69940 | 69949 | 69958 | 69966 | 69975 |
| **1** | 9984 | 9992 | 70001 | 70010 | 70018 | 70027 | 70036 | 70044 | 70053 | 70062 |
| **2** | 70070 | 70079 | 0088 | 0096 | 0105 | 0114 | 0122 | 0131 | 0140 | 0148 |
| **3** | 0157 | 0165 | 0174 | 0183 | 0191 | 0200 | 0209 | 0217 | 0226 | 0234 |
| **4** | 0243 | 0252 | 0260 | 0269 | 0278 | 0286 | 0295 | 0303 | 0312 | 0321 |
| **5** | 0329 | 0338 | 0346 | 0355 | 0364 | 0372 | 0381 | 0389 | 0398 | 0406 |
| **6** | 0415 | 0424 | 0432 | 0441 | 0449 | 0458 | 0467 | 0475 | 0484 | 0492 |
| **7** | 0501 | 0509 | 0518 | 0526 | 0535 | 0544 | 0552 | 0561 | 0569 | 0578 |
| **8** | 0586 | 0595 | 0603 | 0612 | 0621 | 0629 | 0638 | 0646 | 0655 | 0663 |
| **9** | 0672 | 0680 | 0689 | 0697 | 0706 | 0714 | 0723 | 0731 | 0740 | 0749 |
| **510** | 70757 | 70766 | 70774 | 70783 | 70791 | 70800 | 70808 | 70817 | 70825 | 70834 |
| **1** | 0842 | 0851 | 0859 | 0868 | 0876 | 0885 | 0893 | 0902 | 0910 | 0919 |
| **2** | 0927 | 0935 | 0944 | 0952 | 0961 | 0969 | 0978 | 0986 | 0995 | 1003 |
| **3** | 1012 | 1020 | 1029 | 1037 | 1046 | 1054 | 1063 | 1071 | 1079 | 1088 |
| **4** | 1096 | 1105 | 1113 | 1122 | 1130 | 1139 | 1147 | 1155 | 1164 | 1172 |
| **5** | 1181 | 1189 | 1198 | 1206 | 1214 | 1223 | 1231 | 1240 | 1248 | 1257 |
| **6** | 1265 | 1273 | 1282 | 1290 | 1299 | 1307 | 1315 | 1324 | 1332 | 1341 |
| **7** | 1349 | 1357 | 1366 | 1374 | 1383 | 1391 | 1399 | 1408 | 1416 | 1425 |
| **8** | 1433 | 1441 | 1450 | 1458 | 1466 | 1475 | 1483 | 1492 | 1500 | 1508 |
| **9** | 1517 | 1525 | 1533 | 1542 | 1550 | 1559 | 1567 | 1575 | 1584 | 1592 |
| **520** | 71600 | 71609 | 71617 | 71625 | 71634 | 71642 | 71650 | 71659 | 71667 | 71675 |
| **1** | 1684 | 1692 | 1700 | 1709 | 1717 | 1725 | 1734 | 1742 | 1750 | 1759 |
| **2** | 1767 | 1775 | 1784 | 1792 | 1800 | 1809 | 1817 | 1825 | 1834 | 1842 |
| **3** | 1850 | 1858 | 1867 | 1875 | 1883 | 1892 | 1900 | 1908 | 1917 | 1925 |
| **4** | 1933 | 1941 | 1950 | 1958 | 1966 | 1975 | 1983 | 1991 | 1999 | 2008 |
| **5** | 2016 | 2024 | 2032 | 2041 | 2049 | 2057 | 2066 | 2074 | 2082 | 2090 |
| **6** | 2099 | 2107 | 2115 | 2123 | 2132 | 2140 | 2148 | 2156 | 2165 | 2173 |
| **7** | 2181 | 2189 | 2198 | 2206 | 2214 | 2222 | 2230 | 2239 | 2247 | 2255 |
| **8** | 2263 | 2272 | 2280 | 2288 | 2296 | 2304 | 2313 | 2321 | 2329 | 2337 |
| **9** | 2346 | 2354 | 2362 | 2370 | 2378 | 2387 | 2395 | 2403 | 2411 | 2419 |
| **530** | 72428 | 72436 | 72444 | 72452 | 72460 | 72469 | 72477 | 72485 | 72493 | 72501 |
| **1** | 2509 | 2518 | 2526 | 2534 | 2542 | 2550 | 2558 | 2567 | 2575 | 2583 |
| **2** | 2591 | 2599 | 2607 | 2616 | 2624 | 2632 | 2640 | 2648 | 2656 | 2665 |
| **3** | 2673 | 2681 | 2689 | 2697 | 2705 | 2713 | 2722 | 2730 | 2738 | 2746 |
| **4** | 2754 | 2762 | 2770 | 2779 | 2787 | 2795 | 2803 | 2811 | 2819 | 2827 |
| **5** | 2835 | 2843 | 2852 | 2860 | 2868 | 2876 | 2884 | 2892 | 2900 | 2908 |
| **6** | 2916 | 2925 | 2933 | 2941 | 2949 | 2957 | 2965 | 2973 | 2981 | 2989 |
| **7** | 2997 | 3006 | 3014 | 3022 | 3030 | 3038 | 3046 | 3054 | 3062 | 3070 |
| **8** | 3078 | 3086 | 3094 | 3102 | 3111 | 3119 | 3127 | 3135 | 3143 | 3151 |
| **9** | 3159 | 3167 | 3175 | 3183 | 3191 | 3199 | 3207 | 3215 | 3223 | 3231 |
| **540** | 73239 | 73247 | 73255 | 73263 | 73272 | 73280 | 73288 | 73296 | 73304 | 73312 |
| **1** | 3320 | 3328 | 3336 | 3344 | 3352 | 3360 | 3368 | 3376 | 3384 | 3392 |
| **2** | 3400 | 3408 | 3416 | 3424 | 3432 | 3440 | 3448 | 3456 | 3464 | 3472 |
| **3** | 3480 | 3488 | 3496 | 3504 | 3512 | 3520 | 3528 | 3536 | 3544 | 3552 |
| **4** | 3560 | 3568 | 3576 | 3584 | 3592 | 3600 | 3608 | 3616 | 3624 | 3632 |
| **5** | 3640 | 3648 | 3656 | 3664 | 3672 | 3679 | 3687 | 3695 | 3703 | 3711 |
| **6** | 3719 | 3727 | 3735 | 3743 | 3751 | 3759 | 3767 | 3775 | 3783 | 3791 |
| **7** | 3799 | 3807 | 3815 | 3823 | 3830 | 3838 | 3846 | 3854 | 3862 | 3870 |
| **8** | 3878 | 3886 | 3894 | 3902 | 3910 | 3918 | 3926 | 3933 | 3941 | 3949 |
| **9** | 3957 | 3965 | 3973 | 3981 | 3989 | 3997 | 4005 | 4013 | 4020 | 4028 |
| **550** | 74036 | 74044 | 74052 | 74060 | 74068 | 74076 | 74084 | 74092 | 74099 | 74107 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **550** | 74036 | 74044 | 74052 | 74060 | 74068 | 74076 | 74084 | 74092 | 74099 | 74107 |
| **1** | 4115 | 4123 | 4131 | 4139 | 4147 | 4155 | 4162 | 4170 | 4178 | 4186 |
| **2** | 4194 | 4202 | 4210 | 4218 | 4225 | 4233 | 4241 | 4249 | 4257 | 4265 |
| **3** | 4273 | 4280 | 4288 | 4296 | 4304 | 4312 | 4320 | 4327 | 4335 | 4343 |
| **4** | 4351 | 4359 | 4367 | 4374 | 4382 | 4390 | 4398 | 4406 | 4414 | 4421 |
| **5** | 4429 | 4437 | 4445 | 4453 | 4461 | 4468 | 4476 | 4484 | 4492 | 4500 |
| **6** | 4507 | 4515 | 4523 | 4531 | 4539 | 4547 | 4554 | 4562 | 4570 | 4578 |
| **7** | 4586 | 4593 | 4601 | 4609 | 4617 | 4624 | 4632 | 4640 | 4648 | 4656 |
| **8** | 4663 | 4671 | 4679 | 4687 | 4695 | 4702 | 4710 | 4718 | 4726 | 4733 |
| **9** | 4741 | 4749 | 4757 | 4764 | 4772 | 4780 | 4788 | 4796 | 4803 | 4811 |
| **560** | 74819 | 74827 | 74834 | 74842 | 74850 | 74858 | 74865 | 74873 | 74881 | 74889 |
| **1** | 4896 | 4904 | 4912 | 4920 | 4927 | 4935 | 4943 | 4950 | 4958 | 4966 |
| **2** | 4974 | 4981 | 4989 | 4997 | 5005 | 5012 | 5020 | 5028 | 5035 | 5043 |
| **3** | 5051 | 5059 | 5066 | 5074 | 5082 | 5089 | 5097 | 5105 | 5113 | 5120 |
| **4** | 5128 | 5136 | 5143 | 5151 | 5159 | 5166 | 5174 | 5182 | 5189 | 5197 |
| **5** | 5205 | 5213 | 5220 | 5228 | 5236 | 5243 | 5251 | 5259 | 5266 | 5274 |
| **6** | 5282 | 5289 | 5297 | 5305 | 5312 | 5320 | 5328 | 5335 | 5343 | 5351 |
| **7** | 5358 | 5366 | 5374 | 5381 | 5389 | 5397 | 5404 | 5412 | 5420 | 5427 |
| **8** | 5435 | 5442 | 5450 | 5458 | 5465 | 5473 | 5481 | 5488 | 5496 | 5504 |
| **9** | 5511 | 5519 | 5526 | 5534 | 5542 | 5549 | 5557 | 5565 | 5572 | 5580 |
| **570** | 75587 | 75595 | 75603 | 75610 | 75618 | 75626 | 75633 | 75641 | 75648 | 75656 |
| **1** | 5664 | 5671 | 5679 | 5686 | 5694 | 5702 | 5709 | 5717 | 5724 | 5732 |
| **2** | 5740 | 5747 | 5755 | 5762 | 5770 | 5778 | 5785 | 5793 | 5800 | 5808 |
| **3** | 5815 | 5823 | 5831 | 5838 | 5846 | 5853 | 5861 | 5868 | 5876 | 5884 |
| **4** | 5891 | 5899 | 5906 | 5914 | 5921 | 5929 | 5937 | 5944 | 5952 | 5959 |
| **5** | 5967 | 5974 | 5982 | 5989 | 5997 | 6005 | 6012 | 6020 | 6027 | 6035 |
| **6** | 6042 | 6050 | 6057 | 6065 | 6072 | 6080 | 6087 | 6095 | 6103 | 6110 |
| **7** | 6118 | 6125 | 6133 | 6140 | 6148 | 6155 | 6163 | 6170 | 6178 | 6185 |
| **8** | 6193 | 6200 | 6208 | 6215 | 6223 | 6230 | 6238 | 6245 | 6253 | 6260 |
| **9** | 6268 | 6275 | 6283 | 6290 | 6298 | 6305 | 6313 | 6320 | 6328 | 6335 |
| **580** | 76343 | 76350 | 76358 | 76365 | 76373 | 76380 | 76388 | 76395 | 76403 | 76410 |
| **1** | 6418 | 6425 | 6433 | 6440 | 6448 | 6455 | 6462 | 6470 | 6477 | 6485 |
| **2** | 6492 | 6500 | 6507 | 6515 | 6522 | 6530 | 6537 | 6545 | 6552 | 6559 |
| **3** | 6567 | 6574 | 6582 | 6589 | 6597 | 6604 | 6612 | 6619 | 6626 | 6634 |
| **4** | 6641 | 6649 | 6656 | 6664 | 6671 | 6678 | 6686 | 6693 | 6701 | 6708 |
| **5** | 6716 | 6723 | 6730 | 6738 | 6745 | 6753 | 6760 | 6768 | 6775 | 6782 |
| **6** | 6790 | 6797 | 6805 | 6812 | 6819 | 6827 | 6834 | 6842 | 6849 | 6856 |
| **7** | 6864 | 6871 | 6879 | 6886 | 6893 | 6901 | 6908 | 6916 | 6923 | 6930 |
| **8** | 6938 | 6945 | 6953 | 6960 | 6967 | 6975 | 6982 | 6989 | 6997 | 7004 |
| **9** | 7012 | 7019 | 7026 | 7034 | 7041 | 7048 | 7056 | 7063 | 7070 | 7078 |
| **590** | 77085 | 77093 | 77100 | 77107 | 77115 | 77122 | 77129 | 77137 | 77144 | 77151 |
| **1** | 7159 | 7166 | 7173 | 7181 | 7188 | 7195 | 7203 | 7210 | 7217 | 7225 |
| **2** | 7232 | 7240 | 7247 | 7254 | 7262 | 7269 | 7276 | 7283 | 7291 | 7298 |
| **3** | 7305 | 7313 | 7320 | 7327 | 7335 | 7342 | 7349 | 7357 | 7364 | 7371 |
| **4** | 7379 | 7386 | 7393 | 7401 | 7408 | 7415 | 7422 | 7430 | 7437 | 7444 |
| **5** | 7452 | 7459 | 7466 | 7474 | 7481 | 7488 | 7495 | 7503 | 7510 | 7517 |
| **6** | 7525 | 7532 | 7539 | 7546 | 7554 | 7561 | 7568 | 7576 | 7583 | 7590 |
| **7** | 7597 | 7605 | 7612 | 7619 | 7627 | 7634 | 7641 | 7648 | 7656 | 7663 |
| **8** | 7670 | 7677 | 7685 | 7692 | 7699 | 7706 | 7714 | 7721 | 7728 | 7735 |
| **9** | 7743 | 7750 | 7757 | 7764 | 7772 | 7779 | 7786 | 7793 | 7801 | 7808 |
| **600** | 77815 | 77822 | 77830 | 77837 | 77844 | 77851 | 77859 | 77866 | 77873 | 77880 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 600 | 77815 | 77822 | 77830 | 77837 | 77844 | 77851 | 77859 | 77866 | 77873 | 77880 |
| 1 | 7887 | 7895 | 7902 | 7909 | 7916 | 7924 | 7931 | 7938 | 7945 | 7952 |
| 2 | 7960 | 7967 | 7974 | 7981 | 7988 | 7996 | 8003 | 8010 | 8017 | 8025 |
| 3 | 8032 | 8039 | 8046 | 8053 | 8061 | 8068 | 8075 | 8082 | 8089 | 8097 |
| 4 | 8104 | 8111 | 8118 | 8125 | 8132 | 8140 | 8147 | 8154 | 8161 | 8168 |
| 5 | 8176 | 8183 | 8190 | 8197 | 8204 | 8211 | 8219 | 8226 | 8233 | 8240 |
| 6 | 8247 | 8254 | 8262 | 8269 | 8276 | 8283 | 8290 | 8297 | 8305 | 8312 |
| 7 | 8319 | 8326 | 8333 | 8340 | 8347 | 8355 | 8362 | 8369 | 8376 | 8383 |
| 8 | 8390 | 8398 | 8405 | 8412 | 8419 | 8426 | 8433 | 8440 | 8447 | 8455 |
| 9 | 8462 | 8469 | 8476 | 8483 | 8490 | 8497 | 8504 | 8512 | 8519 | 8526 |
| 610 | 78533 | 78540 | 78547 | 78554 | 78561 | 78569 | 78576 | 78583 | 78590 | 78597 |
| 1 | 8604 | 8611 | 8618 | 8625 | 8633 | 8640 | 8647 | 8654 | 8661 | 8668 |
| 2 | 8675 | 8682 | 8689 | 8696 | 8704 | 8711 | 8718 | 8725 | 8732 | 8739 |
| 3 | 8746 | 8753 | 8760 | 8767 | 8774 | 8781 | 8789 | 8796 | 8803 | 8810 |
| 4 | 8817 | 8824 | 8831 | 8838 | 8845 | 8852 | 8859 | 8866 | 8873 | 8880 |
| 5 | 8888 | 8895 | 8902 | 8909 | 8916 | 8923 | 8930 | 8937 | 8944 | 8951 |
| 6 | 8958 | 8965 | 8972 | 8979 | 8986 | 8993 | 9000 | 9007 | 9014 | 9021 |
| 7 | 9029 | 9036 | 9043 | 9050 | 9057 | 9064 | 9071 | 9078 | 9085 | 9092 |
| 8 | 9099 | 9106 | 9113 | 9120 | 9127 | 9134 | 9141 | 9148 | 9155 | 9162 |
| 9 | 9169 | 9176 | 9183 | 9190 | 9197 | 9204 | 9211 | 9218 | 9225 | 9232 |
| 620 | 79239 | 79246 | 79253 | 79260 | 79267 | 79274 | 79281 | 79288 | 79295 | 79302 |
| 1 | 9309 | 9316 | 9323 | 9330 | 9337 | 9344 | 9351 | 9358 | 9365 | 9372 |
| 2 | 9379 | 9386 | 9393 | 9400 | 9407 | 9414 | 9421 | 9428 | 9435 | 9442 |
| 3 | 9449 | 9456 | 9463 | 9470 | 9477 | 9484 | 9491 | 9498 | 9505 | 9511 |
| 4 | 9518 | 9525 | 9532 | 9539 | 9546 | 9553 | 9560 | 9567 | 9574 | 9581 |
| 5 | 9588 | 9595 | 9602 | 9609 | 9616 | 9623 | 9630 | 9637 | 9644 | 9650 |
| 6 | 9657 | 9664 | 9671 | 9678 | 9685 | 9692 | 9699 | 9706 | 9713 | 9720 |
| 7 | 9727 | 9734 | 9741 | 9748 | 9754 | 9761 | 9768 | 9775 | 9782 | 9789 |
| 8 | 9796 | 9803 | 9810 | 9817 | 9824 | 9831 | 9837 | 9844 | 9851 | 9858 |
| 9 | 9865 | 9872 | 9879 | 9886 | 9893 | 9900 | 9906 | 9913 | 9920 | 9927 |
| 630 | 79934 | 79941 | 79948 | 79955 | 79962 | 79969 | 79975 | 79982 | 79989 | 79996 |
| 1 | 80003 | 80010 | 80017 | 80024 | 80030 | 80037 | 80044 | 80051 | 80058 | 80065 |
| 2 | 0072 | 0079 | 0085 | 0092 | 0099 | 0106 | 0113 | 0120 | 0127 | 0134 |
| 3 | 0140 | 0147 | 0154 | 0161 | 0168 | 0175 | 0182 | 0188 | 0195 | 0202 |
| 4 | 0209 | 0216 | 0223 | 0229 | 0236 | 0243 | 0250 | 0257 | 0264 | 0271 |
| 5 | 0277 | 0284 | 0291 | 0298 | 0305 | 0312 | 0318 | 0325 | 0332 | 0339 |
| 6 | 0346 | 0353 | 0359 | 0366 | 0373 | 0380 | 0387 | 0393 | 0400 | 0407 |
| 7 | 0414 | 0421 | 0428 | 0434 | 0441 | 0448 | 0455 | 0462 | 0468 | 0475 |
| 8 | 0482 | 0489 | 0496 | 0502 | 0509 | 0516 | 0523 | 0530 | 0536 | 0543 |
| 9 | 0550 | 0557 | 0564 | 0570 | 0577 | 0584 | 0591 | 0598 | 0604 | 0611 |
| 640 | 80618 | 80625 | 80632 | 80638 | 80645 | 80652 | 80659 | 80665 | 80672 | 80679 |
| 1 | 0686 | 0693 | 0699 | 0706 | 0713 | 0720 | 0726 | 0733 | 0740 | 0747 |
| 2 | 0754 | 0760 | 0767 | 0774 | 0781 | 0787 | 0794 | 0801 | 0808 | 0814 |
| 3 | 0821 | 0828 | 0835 | 0841 | 0848 | 0855 | 0862 | 0868 | 0875 | 0882 |
| 4 | 0889 | 0895 | 0902 | 0909 | 0916 | 0922 | 0929 | 0936 | 0943 | 0949 |
| 5 | 0956 | 0963 | 0969 | 0976 | 0983 | 0990 | 0996 | 1003 | 1010 | 1017 |
| 6 | 1023 | 1030 | 1037 | 1043 | 1050 | 1057 | 1064 | 1070 | 1077 | 1084 |
| 7 | 1090 | 1097 | 1104 | 1111 | 1117 | 1124 | 1131 | 1137 | 1144 | 1151 |
| 8 | 1158 | 1164 | 1171 | 1178 | 1184 | 1191 | 1198 | 1204 | 1211 | 1218 |
| 9 | 1224 | 1231 | 1238 | 1245 | 1251 | 1258 | 1265 | 1271 | 1278 | 1285 |
| 650 | 81291 | 81298 | 81305 | 81311 | 81318 | 81325 | 81331 | 81338 | 81345 | 81351 |

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|---|---|---|---|---|---|---|---|---|---|---|
| **650** | 81291 | 81298 | 81305 | 81311 | 81318 | 81325 | 81331 | 81338 | 81345 | 81351 |
| **1** | 1358 | 1365 | 1371 | 1378 | 1385 | 1391 | 1398 | 1405 | 1411 | 1418 |
| **2** | 1425 | 1431 | 1438 | 1445 | 1451 | 1458 | 1465 | 1471 | 1478 | 1485 |
| **3** | 1491 | 1498 | 1505 | 1511 | 1518 | 1525 | 1531 | 1538 | 1544 | 1551 |
| **4** | 1558 | 1564 | 1571 | 1578 | 1584 | 1591 | 1598 | 1604 | 1611 | 1617 |
| **5** | 1624 | 1631 | 1637 | 1644 | 1651 | 1657 | 1664 | 1671 | 1677 | 1684 |
| **6** | 1690 | 1697 | 1704 | 1710 | 1717 | 1723 | 1730 | 1737 | 1743 | 1750 |
| **7** | 1757 | 1763 | 1770 | 1776 | 1783 | 1790 | 1796 | 1803 | 1809 | 1816 |
| **8** | 1823 | 1829 | 1836 | 1842 | 1849 | 1856 | 1862 | 1869 | 1875 | 1882 |
| **9** | 1889 | 1895 | 1902 | 1908 | 1915 | 1921 | 1928 | 1935 | 1941 | 1948 |
| **660** | 81954 | 81961 | 81968 | 81974 | 81981 | 81987 | 81994 | 82000 | 82007 | 82014 |
| **1** | 2020 | 2027 | 2033 | 2040 | 2046 | 2053 | 2060 | 2066 | 2073 | 2079 |
| **2** | 2086 | 2092 | 2099 | 2105 | 2112 | 2119 | 2125 | 2132 | 2138 | 2145 |
| **3** | 2151 | 2158 | 2164 | 2171 | 2178 | 2184 | 2191 | 2197 | 2204 | 2210 |
| **4** | 2217 | 2223 | 2230 | 2236 | 2243 | 2249 | 2256 | 2263 | 2269 | 2276 |
| **5** | 2282 | 2289 | 2295 | 2302 | 2308 | 2315 | 2321 | 2328 | 2334 | 2341 |
| **6** | 2347 | 2354 | 2360 | 2367 | 2373 | 2380 | 2387 | 2393 | 2400 | 2406 |
| **7** | 2413 | 2419 | 2426 | 2432 | 2439 | 2445 | 2452 | 2458 | 2465 | 2471 |
| **8** | 2478 | 2484 | 2491 | 2497 | 2504 | 2510 | 2517 | 2523 | 2530 | 2536 |
| **9** | 2543 | 2549 | 2556 | 2562 | 2569 | 2575 | 2582 | 2588 | 2595 | 2601 |
| **670** | 82607 | 82614 | 82620 | 82627 | 82633 | 82640 | 82646 | 82653 | 82659 | 82666 |
| **1** | 2672 | 2679 | 2685 | 2692 | 2698 | 2705 | 2711 | 2718 | 2724 | 2730 |
| **2** | 2737 | 2743 | 2750 | 2756 | 2763 | 2769 | 2776 | 2782 | 2789 | 2795 |
| **3** | 2802 | 2808 | 2814 | 2821 | 2827 | 2834 | 2840 | 2847 | 2853 | 2860 |
| **4** | 2866 | 2872 | 2879 | 2885 | 2892 | 2898 | 2905 | 2911 | 2918 | 2924 |
| **5** | 2930 | 2937 | 2943 | 2950 | 2956 | 2963 | 2969 | 2975 | 2982 | 2988 |
| **6** | 2995 | 3001 | 3008 | 3014 | 3020 | 3027 | 3033 | 3040 | 3046 | 3052 |
| **7** | 3059 | 3065 | 3072 | 3078 | 3085 | 3091 | 3097 | 3104 | 3110 | 3117 |
| **8** | 3123 | 3129 | 3136 | 3142 | 3149 | 3155 | 3161 | 3168 | 3174 | 3181 |
| **9** | 3187 | 3193 | 3200 | 3206 | 3213 | 3219 | 3225 | 3232 | 3238 | 3245 |
| **680** | 83251 | 83257 | 83264 | 83270 | 83276 | 83283 | 83289 | 83296 | 83302 | 83308 |
| **1** | 3315 | 3321 | 3327 | 3334 | 3340 | 3347 | 3353 | 3359 | 3366 | 3372 |
| **2** | 3378 | 3385 | 3391 | 3398 | 3404 | 3410 | 3417 | 3423 | 3429 | 3436 |
| **3** | 3442 | 3448 | 3455 | 3461 | 3467 | 3474 | 3480 | 3487 | 3493 | 3499 |
| **4** | 3506 | 3512 | 3518 | 3525 | 3531 | 3537 | 3544 | 3550 | 3556 | 3563 |
| **5** | 3569 | 3575 | 3582 | 3588 | 3594 | 3601 | 3607 | 3613 | 3620 | 3626 |
| **6** | 3632 | 3639 | 3645 | 3651 | 3658 | 3664 | 3670 | 3677 | 3683 | 3689 |
| **7** | 3696 | 3702 | 3708 | 3715 | 3721 | 3727 | 3734 | 3740 | 3746 | 3753 |
| **8** | 3759 | 3765 | 3771 | 3778 | 3784 | 3790 | 3797 | 3803 | 3809 | 3816 |
| **9** | 3822 | 3828 | 3835 | 3841 | 3847 | 3853 | 3860 | 3866 | 3872 | 3879 |
| **690** | 83885 | 83891 | 83897 | 83904 | 83910 | 83916 | 83923 | 83929 | 83935 | 83942 |
| **1** | 3948 | 3954 | 3960 | 3967 | 3973 | 3979 | 3985 | 3992 | 3998 | 4004 |
| **2** | 4011 | 4017 | 4023 | 4029 | 4036 | 4042 | 4048 | 4055 | 4061 | 4067 |
| **3** | 4073 | 4080 | 4086 | 4092 | 4098 | 4105 | 4111 | 4117 | 4123 | 4130 |
| **4** | 4136 | 4142 | 4148 | 4155 | 4161 | 4167 | 4173 | 4180 | 4186 | 4192 |
| **5** | 4198 | 4205 | 4211 | 4217 | 4223 | 4230 | 4236 | 4242 | 4248 | 4255 |
| **6** | 4261 | 4267 | 4273 | 4280 | 4286 | 4292 | 4298 | 4305 | 4311 | 4317 |
| **7** | 4323 | 4330 | 4336 | 4342 | 4348 | 4354 | 4361 | 4367 | 4373 | 4379 |
| **8** | 4386 | 4392 | 4398 | 4404 | 4410 | 4417 | 4423 | 4429 | 4435 | 4442 |
| **9** | 4448 | 4454 | 4460 | 4466 | 4473 | 4479 | 4485 | 4491 | 4497 | 4504 |
| **700** | 84510 | 84516 | 84522 | 84528 | 84535 | 84541 | 84547 | 84553 | 84559 | 84566 |

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|---|---|---|---|---|---|---|---|---|---|---|
| **750** | 87506 | 87512 | 87518 | 87523 | 87529 | 87535 | 87541 | 87547 | 87552 | 87558 |
| **1** | 7564 | 7570 | 7576 | 7581 | 7587 | 7593 | 7599 | 7604 | 7610 | 7616 |
| **2** | 7622 | 7628 | 7633 | 7639 | 7645 | 7651 | 7656 | 7662 | 7668 | 7674 |
| **3** | 7679 | 7685 | 7691 | 7697 | 7703 | 7708 | 7714 | 7720 | 7726 | 7731 |
| **4** | 7737 | 7743 | 7749 | 7754 | 7760 | 7766 | 7772 | 7777 | 7783 | 7789 |
| **5** | 7795 | 7800 | 7806 | 7812 | 7818 | 7823 | 7829 | 7835 | 7841 | 7846 |
| **6** | 7852 | 7858 | 7864 | 7869 | 7875 | 7881 | 7887 | 7892 | 7898 | 7904 |
| **7** | 7910 | 7915 | 7921 | 7927 | 7933 | 7938 | 7944 | 7950 | 7955 | 7961 |
| **8** | 7967 | 7973 | 7978 | 7984 | 7990 | 7996 | 8001 | 8007 | 8013 | 8018 |
| **9** | 8024 | 8030 | 8036 | 8041 | 8047 | 8053 | 8058 | 8064 | 8070 | 8076 |
| **760** | 88081 | 88087 | 88093 | 88098 | 88104 | 88110 | 88116 | 88121 | 88127 | 88133 |
| **1** | 8138 | 8144 | 8150 | 8156 | 8161 | 8167 | 8173 | 8178 | 8184 | 8190 |
| **2** | 8195 | 8201 | 8207 | 8213 | 8218 | 8224 | 8230 | 8235 | 8241 | 8247 |
| **3** | 8252 | 8258 | 8264 | 8270 | 8275 | 8281 | 8287 | 8292 | 8298 | 8304 |
| **4** | 8309 | 8315 | 8321 | 8326 | 8332 | 8338 | 8343 | 8349 | 8355 | 8360 |
| **5** | 8366 | 8372 | 8377 | 8383 | 8389 | 8395 | 8400 | 8406 | 8412 | 8417 |
| **6** | 8423 | 8429 | 8434 | 8440 | 8446 | 8451 | 8457 | 8463 | 8468 | 8474 |
| **7** | 8480 | 8485 | 8491 | 8497 | 8502 | 8508 | 8513 | 8519 | 8525 | 8530 |
| **8** | 8536 | 8542 | 8547 | 8553 | 8559 | 8564 | 8570 | 8576 | 8581 | 8587 |
| **9** | 8593 | 8598 | 8604 | 8610 | 8615 | 8621 | 8627 | 8632 | 8638 | 8643 |
| **770** | 88649 | 88655 | 88660 | 88666 | 88672 | 88677 | 88683 | 88689 | 88694 | 88700 |
| **1** | 8705 | 8711 | 8717 | 8722 | 8728 | 8734 | 8739 | 8745 | 8750 | 8756 |
| **2** | 8762 | 8767 | 8773 | 8779 | 8784 | 8790 | 8795 | 8801 | 8807 | 8812 |
| **3** | 8818 | 8824 | 8829 | 8835 | 8840 | 8846 | 8852 | 8857 | 8863 | 8868 |
| **4** | 8874 | 8880 | 8885 | 8891 | 8897 | 8902 | 8908 | 8913 | 8919 | 8925 |
| **5** | 8930 | 8936 | 8941 | 8947 | 8953 | 8958 | 8964 | 8969 | 8975 | 8981 |
| **6** | 8986 | 8992 | 8997 | 9003 | 9009 | 9014 | 9020 | 9025 | 9031 | 9037 |
| **7** | 9042 | 9048 | 9053 | 9059 | 9064 | 9070 | 9076 | 9081 | 9087 | 9092 |
| **8** | 9098 | 9104 | 9109 | 9115 | 9120 | 9126 | 9131 | 9137 | 9143 | 9148 |
| **9** | 9154 | 9159 | 9165 | 9170 | 9176 | 9182 | 9187 | 9193 | 9198 | 9204 |
| **780** | 89209 | 89215 | 89221 | 89226 | 89232 | 89237 | 89243 | 89248 | 89254 | 89260 |
| **1** | 9265 | 9271 | 9276 | 9282 | 9287 | 9293 | 9298 | 9304 | 9310 | 9315 |
| **2** | 9321 | 9326 | 9332 | 9337 | 9343 | 9348 | 9354 | 9360 | 9365 | 9371 |
| **3** | 9376 | 9382 | 9387 | 9393 | 9398 | 9404 | 9409 | 9415 | 9421 | 9426 |
| **4** | 9432 | 9437 | 9443 | 9448 | 9454 | 9459 | 9465 | 9470 | 9476 | 9481 |
| **5** | 9487 | 9492 | 9498 | 9504 | 9509 | 9515 | 9520 | 9526 | 9531 | 9537 |
| **6** | 9542 | 9548 | 9553 | 9559 | 9564 | 9570 | 9575 | 9581 | 9586 | 9592 |
| **7** | 9597 | 9603 | 9609 | 9614 | 9620 | 9625 | 9631 | 9636 | 9642 | 9647 |
| **8** | 9653 | 9658 | 9664 | 9669 | 9675 | 9680 | 9686 | 9691 | 9697 | 9702 |
| **9** | 9708 | 9713 | 9719 | 9724 | 9730 | 9735 | 9741 | 9746 | 9752 | 9757 |
| **790** | 89763 | 89768 | 89774 | 89779 | 89785 | 89790 | 89796 | 89801 | 89807 | 89812 |
| **1** | 9818 | 9823 | 9829 | 9834 | 9840 | 9845 | 9851 | 9856 | 9862 | 9867 |
| **2** | 9873 | 9878 | 9883 | 9889 | 9894 | 9900 | 9905 | 9911 | 9916 | 9922 |
| **3** | 9927 | 9933 | 9938 | 9944 | 9949 | 9955 | 9960 | 9966 | 9971 | 9977 |
| **4** | 9982 | 9988 | 9993 | 9998 | 90004 | 90009 | 90015 | 90020 | 90026 | 90031 |
| **5** | 90037 | 90042 | 90048 | 90053 | 0059 | 0064 | 0069 | 0075 | 0080 | 0086 |
| **6** | 0091 | 0097 | 0102 | 0108 | 0113 | 0119 | 0124 | 0129 | 0135 | 0140 |
| **7** | 0146 | 0151 | 0157 | 0162 | 0168 | 0173 | 0179 | 0184 | 0189 | 0195 |
| **8** | 0200 | 0206 | 0211 | 0217 | 0222 | 0227 | 0233 | 0238 | 0244 | 0249 |
| **9** | 0255 | 0260 | 0266 | 0271 | 0276 | 0282 | 0287 | 0293 | 0298 | 0304 |
| **800** | 90309 | 90314 | 90320 | 90325 | 90331 | 90336 | 90342 | 90347 | 90352 | 90358 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
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| **2** | 0417 | 0423 | 0428 | 0434 | 0439 | 0445 | 0450 | 0455 | 0461 | 0466 |
| **3** | 0472 | 0477 | 0482 | 0488 | 0493 | 0499 | 0504 | 0509 | 0515 | 0520 |
| **4** | 0526 | 0531 | 0536 | 0542 | 0547 | 0553 | 0558 | 0563 | 0569 | 0574 |
| **5** | 0580 | 0585 | 0590 | 0596 | 0601 | 0607 | 0612 | 0617 | 0623 | 0628 |
| **6** | 0634 | 0639 | 0644 | 0650 | 0655 | 0660 | 0666 | 0671 | 0677 | 0682 |
| **7** | 0687 | 0693 | 0698 | 0703 | 0709 | 0714 | 0720 | 0725 | 0730 | 0736 |
| **8** | 0741 | 0747 | 0752 | 0757 | 0763 | 0768 | 0773 | 0779 | 0784 | 0789 |
| **9** | 0795 | 0800 | 0806 | 0811 | 0816 | 0822 | 0827 | 0832 | 0838 | 0843 |
| **810** | 90849 | 90854 | 90859 | 90865 | 90870 | 90875 | 90881 | 90886 | 90891 | 90897 |
| **1** | 0902 | 0907 | 0913 | 0918 | 0924 | 0929 | 0934 | 0940 | 0945 | 0950 |
| **2** | 0956 | 0961 | 0966 | 0972 | 0977 | 0982 | 0988 | 0993 | 0998 | 1004 |
| **3** | 1009 | 1014 | 1020 | 1025 | 1030 | 1036 | 1041 | 1046 | 1052 | 1057 |
| **4** | 1062 | 1068 | 1073 | 1078 | 1084 | 1089 | 1094 | 1100 | 1105 | 1110 |
| **5** | 1116 | 1121 | 1126 | 1132 | 1137 | 1142 | 1148 | 1153 | 1158 | 1164 |
| **6** | 1169 | 1174 | 1180 | 1185 | 1190 | 1196 | 1201 | 1206 | 1212 | 1217 |
| **7** | 1222 | 1228 | 1233 | 1238 | 1243 | 1249 | 1254 | 1259 | 1265 | 1270 |
| **8** | 1275 | 1281 | 1286 | 1291 | 1297 | 1302 | 1307 | 1312 | 1318 | 1323 |
| **9** | 1328 | 1334 | 1339 | 1344 | 1350 | 1355 | 1360 | 1365 | 1371 | 1376 |
| **820** | 91381 | 91387 | 91392 | 91397 | 91403 | 91408 | 91413 | 91418 | 91424 | 91429 |
| **1** | 1434 | 1440 | 1445 | 1450 | 1455 | 1461 | 1466 | 1471 | 1477 | 1482 |
| **2** | 1487 | 1492 | 1498 | 1503 | 1508 | 1514 | 1519 | 1524 | 1529 | 1535 |
| **3** | 1540 | 1545 | 1551 | 1556 | 1561 | 1566 | 1572 | 1577 | 1582 | 1587 |
| **4** | 1593 | 1598 | 1603 | 1609 | 1614 | 1619 | 1624 | 1630 | 1635 | 1640 |
| **5** | 1645 | 1651 | 1656 | 1661 | 1666 | 1672 | 1677 | 1682 | 1687 | 1693 |
| **6** | 1698 | 1703 | 1709 | 1714 | 1719 | 1724 | 1730 | 1735 | 1740 | 1745 |
| **7** | 1751 | 1756 | 1761 | 1766 | 1772 | 1777 | 1782 | 1787 | 1793 | 1798 |
| **8** | 1803 | 1808 | 1814 | 1819 | 1824 | 1829 | 1834 | 1840 | 1845 | 1850 |
| **9** | 1855 | 1861 | 1866 | 1871 | 1876 | 1882 | 1887 | 1892 | 1897 | 1903 |
| **830** | 91908 | 91913 | 91918 | 91924 | 91929 | 91934 | 91939 | 91944 | 91950 | 91955 |
| **1** | 1960 | 1965 | 1971 | 1976 | 1981 | 1986 | 1991 | 1997 | 2002 | 2007 |
| **2** | 2012 | 2018 | 2023 | 2028 | 2033 | 2038 | 2044 | 2049 | 2054 | 2059 |
| **3** | 2065 | 2070 | 2075 | 2080 | 2085 | 2091 | 2096 | 2101 | 2106 | 2111 |
| **4** | 2117 | 2122 | 2127 | 2132 | 2137 | 2143 | 2148 | 2153 | 2158 | 2163 |
| **5** | 2169 | 2174 | 2179 | 2184 | 2189 | 2195 | 2200 | 2205 | 2210 | 2215 |
| **6** | 2221 | 2226 | 2231 | 2236 | 2241 | 2247 | 2252 | 2257 | 2262 | 2267 |
| **7** | 2273 | 2278 | 2283 | 2288 | 2293 | 2298 | 2304 | 2309 | 2314 | 2319 |
| **8** | 2324 | 2330 | 2335 | 2340 | 2345 | 2350 | 2355 | 2361 | 2366 | 2371 |
| **9** | 2376 | 2381 | 2387 | 2392 | 2397 | 2402 | 2407 | 2412 | 2418 | 2423 |
| **840** | 92428 | 92433 | 92438 | 92443 | 92449 | 92454 | 92459 | 92464 | 92469 | 92474 |
| **1** | 2480 | 2485 | 2490 | 2495 | 2500 | 2505 | 2511 | 2516 | 2521 | 2526 |
| **2** | 2531 | 2536 | 2542 | 2547 | 2552 | 2557 | 2562 | 2567 | 2572 | 2578 |
| **3** | 2583 | 2588 | 2593 | 2598 | 2603 | 2609 | 2614 | 2619 | 2624 | 2629 |
| **4** | 2634 | 2639 | 2645 | 2650 | 2655 | 2660 | 2665 | 2670 | 2675 | 2681 |
| **5** | 2686 | 2691 | 2696 | 2701 | 2706 | 2711 | 2716 | 2722 | 2727 | 2732 |
| **6** | 2737 | 2742 | 2747 | 2752 | 2758 | 2763 | 2768 | 2773 | 2778 | 2783 |
| **7** | 2788 | 2793 | 2799 | 2804 | 2809 | 2814 | 2819 | 2824 | 2829 | 2834 |
| **8** | 2840 | 2845 | 2850 | 2855 | 2860 | 2865 | 2870 | 2875 | 2881 | 2886 |
| **9** | 2891 | 2896 | 2901 | 2906 | 2911 | 2916 | 2921 | 2927 | 2932 | 2937 |
| **850** | 92942 | 92947 | 92952 | 92957 | 92962 | 92967 | 92973 | 92978 | 92983 | 92988 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **850** | 92942 | 92947 | 92952 | 92957 | 92962 | 92967 | 92973 | 92978 | 92983 | 92988 |
| **1** | 2993 | 2998 | 3003 | 3008 | 3013 | 3018 | 3024 | 3029 | 3034 | 3039 |
| **2** | 3044 | 3049 | 3054 | 3059 | 3064 | 3069 | 3075 | 3080 | 3085 | 3090 |
| **3** | 3095 | 3100 | 3105 | 3110 | 3115 | 3120 | 3125 | 3131 | 3136 | 3141 |
| **4** | 3146 | 3151 | 3156 | 3161 | 3166 | 3171 | 3176 | 3181 | 3186 | 3192 |
| **5** | 3197 | 3202 | 3207 | 3212 | 3217 | 3222 | 3227 | 3232 | 3237 | 3242 |
| **6** | 3247 | 3252 | 3258 | 3263 | 3268 | 3273 | 3278 | 3283 | 3288 | 3293 |
| **7** | 3298 | 3303 | 3308 | 3313 | 3318 | 3323 | 3328 | 3334 | 3339 | 3344 |
| **8** | 3349 | 3354 | 3359 | 3364 | 3369 | 3374 | 3379 | 3384 | 3389 | 3394 |
| **9** | 3399 | 3404 | 3409 | 3414 | 3420 | 3425 | 3430 | 3435 | 3440 | 3445 |
| **860** | 93450 | 93455 | 93460 | 93465 | 93470 | 93475 | 93480 | 93485 | 93490 | 93495 |
| **1** | 3500 | 3505 | 3510 | 3515 | 3520 | 3526 | 3531 | 3536 | 3541 | 3546 |
| **2** | 3551 | 3556 | 3561 | 3566 | 3571 | 3576 | 3581 | 3586 | 3591 | 3596 |
| **3** | 3601 | 3606 | 3611 | 3616 | 3621 | 3626 | 3631 | 3636 | 3641 | 3646 |
| **4** | 3651 | 3656 | 3661 | 3666 | 3671 | 3676 | 3682 | 3687 | 3692 | 3697 |
| **5** | 3702 | 3707 | 3712 | 3717 | 3722 | 3727 | 3732 | 3737 | 3742 | 3747 |
| **6** | 3752 | 3757 | 3762 | 3767 | 3772 | 3777 | 3782 | 3787 | 3792 | 3797 |
| **7** | 3802 | 3807 | 3812 | 3817 | 3822 | 3827 | 3832 | 3837 | 3842 | 3847 |
| **8** | 3852 | 3857 | 3862 | 3867 | 3872 | 3877 | 3882 | 3887 | 3892 | 3897 |
| **9** | 3902 | 3907 | 3912 | 3917 | 3922 | 3927 | 3932 | 3937 | 3942 | 3947 |
| **870** | 93952 | 93957 | 93962 | 93967 | 93972 | 93977 | 93982 | 93987 | 93992 | 93997 |
| **1** | 4002 | 4007 | 4012 | 4017 | 4022 | 4027 | 4032 | 4037 | 4042 | 4047 |
| **2** | 4052 | 4057 | 4062 | 4067 | 4072 | 4077 | 4082 | 4086 | 4091 | 4096 |
| **3** | 4101 | 4106 | 4111 | 4116 | 4121 | 4126 | 4131 | 4136 | 4141 | 4146 |
| **4** | 4151 | 4156 | 4161 | 4166 | 4171 | 4176 | 4181 | 4186 | 4191 | 4196 |
| **5** | 4201 | 4206 | 4211 | 4216 | 4221 | 4226 | 4231 | 4236 | 4240 | 4245 |
| **6** | 4250 | 4255 | 4260 | 4265 | 4270 | 4275 | 4280 | 4285 | 4290 | 4295 |
| **7** | 4300 | 4305 | 4310 | 4315 | 4320 | 4325 | 4330 | 4335 | 4340 | 4345 |
| **8** | 4349 | 4354 | 4359 | 4364 | 4369 | 4374 | 4379 | 4384 | 4389 | 4394 |
| **9** | 4399 | 4404 | 4409 | 4414 | 4419 | 4424 | 4429 | 4433 | 4438 | 4443 |
| **880** | 94448 | 94453 | 94458 | 94463 | 94468 | 94473 | 94478 | 94483 | 94488 | 94493 |
| **1** | 4498 | 4503 | 4507 | 4512 | 4517 | 4522 | 4527 | 4532 | 4537 | 4542 |
| **2** | 4547 | 4552 | 4557 | 4562 | 4567 | 4571 | 4576 | 4581 | 4586 | 4591 |
| **3** | 4596 | 4601 | 4606 | 4611 | 4616 | 4621 | 4626 | 4630 | 4635 | 4640 |
| **4** | 4645 | 4650 | 4655 | 4660 | 4665 | 4670 | 4675 | 4680 | 4685 | 4689 |
| **5** | 4694 | 4699 | 4704 | 4709 | 4714 | 4719 | 4724 | 4729 | 4734 | 4738 |
| **6** | 4743 | 4748 | 4753 | 4758 | 4763 | 4768 | 4773 | 4778 | 4783 | 4787 |
| **7** | 4792 | 4797 | 4802 | 4807 | 4812 | 4817 | 4822 | 4827 | 4832 | 4836 |
| **8** | 4841 | 4846 | 4851 | 4856 | 4861 | 4866 | 4871 | 4876 | 4880 | 4885 |
| **9** | 4890 | 4895 | 4900 | 4905 | 4910 | 4915 | 4919 | 4924 | 4929 | 4934 |
| **890** | 94939 | 94944 | 94949 | 94954 | 94959 | 94963 | 94968 | 94973 | 94978 | 94983 |
| **1** | 4988 | 4993 | 4998 | 5002 | 5007 | 5012 | 5017 | 5022 | 5027 | 5032 |
| **2** | 5036 | 5041 | 5046 | 5051 | 5056 | 5061 | 5066 | 5071 | 5075 | 5080 |
| **3** | 5085 | 5090 | 5095 | 5100 | 5105 | 5109 | 5114 | 5119 | 5124 | 5129 |
| **4** | 5134 | 5139 | 5143 | 5148 | 5153 | 5158 | 5163 | 5168 | 5173 | 5177 |
| **5** | 5182 | 5187 | 5192 | 5197 | 5202 | 5207 | 5211 | 5216 | 5221 | 5226 |
| **6** | 5231 | 5236 | 5240 | 5245 | 5250 | 5255 | 5260 | 5265 | 5270 | 5274 |
| **7** | 5279 | 5284 | 5289 | 5294 | 5299 | 5303 | 5308 | 5313 | 5318 | 5323 |
| **8** | 5328 | 5332 | 5337 | 5342 | 5347 | 5352 | 5357 | 5361 | 5366 | 5371 |
| **9** | 5376 | 5381 | 5386 | 5390 | 5395 | 5400 | 5405 | 5410 | 5415 | 5419 |
| **900** | 95424 | 95429 | 95434 | 95[illegible] | 95444 | 95448 | 95453 | 95458 | 95463 | 95468 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **900** | 95424 | 95429 | 95434 | 95439 | 95444 | 95448 | 95453 | 95458 | 95463 | 95468 |
| **1** | 5472 | 5477 | 5482 | 5487 | 5492 | 5497 | 5501 | 5506 | 5511 | 5516 |
| **2** | 5521 | 5525 | 5530 | 5535 | 5540 | 5545 | 5550 | 5554 | 5559 | 5564 |
| **3** | 5569 | 5574 | 5578 | 5583 | 5588 | 5593 | 5598 | 5602 | 5607 | 5612 |
| **4** | 5617 | 5622 | 5626 | 5631 | 5636 | 5641 | 5646 | 5650 | 5655 | 5660 |
| **5** | 5665 | 5670 | 5674 | 5679 | 5684 | 5689 | 5694 | 5698 | 5703 | 5708 |
| **6** | 5713 | 5718 | 5722 | 5727 | 5732 | 5737 | 5742 | 5746 | 5751 | 5756 |
| **7** | 5761 | 5766 | 5770 | 5775 | 5780 | 5785 | 5789 | 5794 | 5799 | 5804 |
| **8** | 5809 | 5813 | 5818 | 5823 | 5828 | 5832 | 5837 | 5842 | 5847 | 5852 |
| **9** | 5856 | 5861 | 5866 | 5871 | 5875 | 5880 | 5885 | 5890 | 5895 | 5899 |
| **910** | 95904 | 95909 | 95914 | 95918 | 95923 | 95928 | 95933 | 95938 | 95942 | 95947 |
| **1** | 5952 | 5957 | 5961 | 5966 | 5971 | 5976 | 5980 | 5985 | 5990 | 5995 |
| **2** | 5999 | 6004 | 6009 | 6014 | 6019 | 6023 | 6028 | 6033 | 6038 | 6042 |
| **3** | 6047 | 6052 | 6057 | 6061 | 6066 | 6071 | 6076 | 6080 | 6085 | 6090 |
| **4** | 6095 | 6099 | 6104 | 6109 | 6114 | 6118 | 6123 | 6128 | 6133 | 6137 |
| **5** | 6142 | 6147 | 6152 | 6156 | 6161 | 6166 | 6171 | 6175 | 6180 | 6185 |
| **6** | 6190 | 6194 | 6199 | 6204 | 6209 | 6213 | 6218 | 6223 | 6227 | 6232 |
| **7** | 6237 | 6242 | 6246 | 6251 | 6256 | 6261 | 6265 | 6270 | 6275 | 6280 |
| **8** | 6284 | 6289 | 6294 | 6298 | 6303 | 6308 | 6313 | 6317 | 6322 | 6327 |
| **9** | 6332 | 6336 | 6341 | 6346 | 6350 | 6355 | 6360 | 6365 | 6369 | 6374 |
| **920** | 96379 | 96384 | 96388 | 96393 | 96398 | 96402 | 96407 | 96412 | 96417 | 96421 |
| **1** | 6426 | 6431 | 6435 | 6440 | 6445 | 6450 | 6454 | 6459 | 6464 | 6468 |
| **2** | 6473 | 6478 | 6483 | 6487 | 6492 | 6497 | 6501 | 6506 | 6511 | 6515 |
| **3** | 6520 | 6525 | 6530 | 6534 | 6539 | 6544 | 6548 | 6553 | 6558 | 6562 |
| **4** | 6567 | 6572 | 6577 | 6581 | 6586 | 6591 | 6595 | 6600 | 6605 | 6609 |
| **5** | 6614 | 6619 | 6624 | 6628 | 6633 | 6638 | 6642 | 6647 | 6652 | 6656 |
| **6** | 6661 | 6666 | 6670 | 6675 | 6680 | 6685 | 6689 | 6694 | 6699 | 6703 |
| **7** | 6708 | 6713 | 6717 | 6722 | 6727 | 6731 | 6736 | 6741 | 6745 | 6750 |
| **8** | 6755 | 6759 | 6764 | 6769 | 6774 | 6778 | 6783 | 6788 | 6792 | 6797 |
| **9** | 6802 | 6806 | 6811 | 6816 | 6820 | 6825 | 6830 | 6834 | 6839 | 6844 |
| **930** | 96848 | 96853 | 96858 | 96862 | 96867 | 96872 | 96876 | 96881 | 96886 | 96890 |
| **1** | 6895 | 6900 | 6904 | 6909 | 6914 | 6918 | 6923 | 6928 | 6932 | 6937 |
| **2** | 6942 | 6946 | 6951 | 6956 | 6960 | 6965 | 6970 | 6974 | 6979 | 6984 |
| **3** | 6988 | 6993 | 6997 | 7002 | 7007 | 7011 | 7016 | 7021 | 7025 | 7030 |
| **4** | 7035 | 7039 | 7044 | 7049 | 7053 | 7058 | 7063 | 7067 | 7072 | 7077 |
| **5** | 7081 | 7086 | 7090 | 7095 | 7100 | 7104 | 7109 | 7114 | 7118 | 7123 |
| **6** | 7128 | 7132 | 7137 | 7142 | 7146 | 7151 | 7155 | 7160 | 7165 | 7169 |
| **7** | 7174 | 7179 | 7183 | 7188 | 7192 | 7197 | 7202 | 7206 | 7211 | 7216 |
| **8** | 7220 | 7225 | 7230 | 7234 | 7239 | 7243 | 7248 | 7253 | 7257 | 7262 |
| **9** | 7267 | 7271 | 7276 | 7280 | 7285 | 7290 | 7294 | 7299 | 7304 | 7308 |
| **940** | 97313 | 97317 | 97322 | 97327 | 97331 | 97336 | 97340 | 97345 | 97350 | 97354 |
| **1** | 7359 | 7364 | 7368 | 7373 | 7377 | 7382 | 7387 | 7391 | 7396 | 7400 |
| **2** | 7405 | 7410 | 7414 | 7419 | 7424 | 7428 | 7433 | 7437 | 7442 | 7447 |
| **3** | 7451 | 7456 | 7460 | 7465 | 7470 | 7474 | 7479 | 7483 | 7488 | 7493 |
| **4** | 7497 | 7502 | 7506 | 7511 | 7516 | 7520 | 7525 | 7529 | 7534 | 7539 |
| **5** | 7543 | 7548 | 7552 | 7557 | 7562 | 7566 | 7571 | 7575 | 7580 | 7585 |
| **6** | 7589 | 7594 | 7598 | 7603 | 7607 | 7612 | 7617 | 7621 | 7626 | 7630 |
| **7** | 7635 | 7640 | 7644 | 7649 | 7653 | 7658 | 7663 | 7667 | 7672 | 7676 |
| **8** | 7681 | 7685 | 7690 | 7695 | 7699 | 7704 | 7708 | 7713 | 7717 | 7722 |
| **9** | 7727 | 7731 | 7736 | 7740 | 7745 | 7749 | 7754 | 7759 | 7763 | 7768 |
| **950** | 97772 | 97777 | 97782 | 97786 | 97791 | 97795 | 97800 | 97804 | 97809 | 97813 |

| N | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **950** | 97772 | 97777 | 97782 | 97786 | 97791 | 97795 | 97800 | 97804 | 97809 | 97813 |
| **1** | 7818 | 7823 | 7827 | 7832 | 7836 | 7841 | 7845 | 7850 | 7855 | 7859 |
| **2** | 7864 | 7868 | 7873 | 7877 | 7882 | 7886 | 7891 | 7896 | 7900 | 7905 |
| **3** | 7909 | 7914 | 7918 | 7923 | 7928 | 7932 | 7937 | 7941 | 7946 | 7950 |
| **4** | 7955 | 7959 | 7964 | 7968 | 7973 | 7978 | 7982 | 7987 | 7991 | 7996 |
| **5** | 8000 | 8005 | 8009 | 8014 | 8019 | 8023 | 8028 | 8032 | 8037 | 8041 |
| **6** | 8046 | 8050 | 8055 | 8059 | 8064 | 8068 | 8073 | 8078 | 8082 | 8087 |
| **7** | 8091 | 8096 | 8100 | 8105 | 8109 | 8114 | 8118 | 8123 | 8127 | 8132 |
| **8** | 8137 | 8141 | 8146 | 8150 | 8155 | 8159 | 8164 | 8168 | 8173 | 8177 |
| **9** | 8182 | 8186 | 8191 | 8195 | 8200 | 8204 | 8209 | 8214 | 8218 | 8223 |
| **960** | 98227 | 98232 | 98236 | 98241 | 98245 | 98250 | 98254 | 98259 | 98263 | 98268 |
| **1** | 8272 | 8277 | 8281 | 8286 | 8290 | 8295 | 8299 | 8304 | 8308 | 8313 |
| **2** | 8318 | 8322 | 8327 | 8331 | 8336 | 8340 | 8345 | 8349 | 8354 | 8358 |
| **3** | 8363 | 8367 | 8372 | 8376 | 8381 | 8385 | 8390 | 8394 | 8399 | 8403 |
| **4** | 8408 | 8412 | 8417 | 8421 | 8426 | 8430 | 8435 | 8439 | 8444 | 8448 |
| **5** | 8453 | 8457 | 8462 | 8466 | 8471 | 8475 | 8480 | 8484 | 8489 | 8493 |
| **6** | 8498 | 8502 | 8507 | 8511 | 8516 | 8520 | 8525 | 8529 | 8534 | 8538 |
| **7** | 8543 | 8547 | 8552 | 8556 | 8561 | 8565 | 8570 | 8574 | 8579 | 8583 |
| **8** | 8588 | 8592 | 8597 | 8601 | 8605 | 8610 | 8614 | 8619 | 8623 | 8628 |
| **9** | 8632 | 8637 | 8641 | 8646 | 8650 | 8655 | 8659 | 8664 | 8668 | 8673 |
| **970** | 98677 | 98682 | 98686 | 98691 | 98695 | 98700 | 98704 | 98709 | 98713 | 98717 |
| **1** | 8722 | 8726 | 8731 | 8735 | 8740 | 8744 | 8749 | 8753 | 8758 | 8762 |
| **2** | 8767 | 8771 | 8776 | 8780 | 8784 | 8789 | 8793 | 8798 | 8802 | 8807 |
| **3** | 8811 | 8816 | 8820 | 8825 | 8829 | 8834 | 8838 | 8843 | 8847 | 8851 |
| **4** | 8856 | 8860 | 8865 | 8869 | 8874 | 8878 | 8883 | 8887 | 8892 | 8896 |
| **5** | 8900 | 8905 | 8909 | 8914 | 8918 | 8923 | 8927 | 8932 | 8936 | 8941 |
| **6** | 8945 | 8949 | 8954 | 8958 | 8963 | 8967 | 8972 | 8976 | 8981 | 8985 |
| **7** | 8989 | 8994 | 8998 | 9003 | 9007 | 9012 | 9016 | 9021 | 9025 | 9029 |
| **8** | 9034 | 9038 | 9043 | 9047 | 9052 | 9056 | 9061 | 9065 | 9069 | 9074 |
| **9** | 9078 | 9083 | 9087 | 9092 | 9096 | 9100 | 9105 | 9109 | 9114 | 9118 |
| **980** | 99123 | 99127 | 99131 | 99136 | 99140 | 99145 | 99149 | 99154 | 99158 | 99162 |
| **1** | 9167 | 9171 | 9176 | 9180 | 9185 | 9189 | 9193 | 9198 | 9202 | 9207 |
| **2** | 9211 | 9216 | 9220 | 9224 | 9229 | 9233 | 9238 | 9242 | 9247 | 9251 |
| **3** | 9255 | 9260 | 9264 | 9269 | 9273 | 9277 | 9282 | 9286 | 9291 | 9295 |
| **4** | 9300 | 9304 | 9308 | 9313 | 9317 | 9322 | 9326 | 9330 | 9335 | 9339 |
| **5** | 9344 | 9348 | 9352 | 9357 | 9361 | 9366 | 9370 | 9374 | 9379 | 9383 |
| **6** | 9388 | 9392 | 9396 | 9401 | 9405 | 9410 | 9414 | 9419 | 9423 | 9427 |
| **7** | 9432 | 9436 | 9441 | 9445 | 9449 | 9454 | 9458 | 9463 | 9467 | 9471 |
| **8** | 9476 | 9480 | 9484 | 9489 | 9493 | 9498 | 9502 | 9506 | 9511 | 9515 |
| **9** | 9520 | 9524 | 9528 | 9533 | 9537 | 9542 | 9546 | 9550 | 9555 | 9559 |
| **990** | 99564 | 99568 | 99572 | 99577 | 99581 | 99585 | 99590 | 99594 | 99599 | 99603 |
| **1** | 9607 | 9612 | 9616 | 9621 | 9625 | 9629 | 9634 | 9638 | 9642 | 9647 |
| **2** | 9651 | 9656 | 9660 | 9664 | 9669 | 9673 | 9677 | 9682 | 9686 | 9691 |
| **3** | 9695 | 9699 | 9704 | 9708 | 9712 | 9717 | 9721 | 9726 | 9730 | 9734 |
| **4** | 9739 | 9743 | 9747 | 9752 | 9756 | 9760 | 9765 | 9769 | 9774 | 9778 |
| **5** | 9782 | 9787 | 9791 | 9795 | 9800 | 9804 | 9808 | 9813 | 9817 | 9822 |
| **6** | 9826 | 9830 | 9835 | 9839 | 9843 | 9848 | 9852 | 9856 | 9861 | 9865 |
| **7** | 9870 | 9874 | 9878 | 9883 | 9887 | 9891 | 9896 | 9900 | 9904 | 9909 |
| **8** | 9913 | 9917 | 9922 | 9926 | 9930 | 9935 | 9939 | 9944 | 9948 | 9952 |
| **9** | 9957 | 9961 | 9965 | 9970 | 9974 | 9978 | 9983 | 9987 | 9991 | 9996 |
| **1000** | 00000 | 00004 | 00009 | 00013 | 00017 | 00022 | 00026 | 00030 | 00035 | 00039 |

| ′ | 0° | | 1° | | 2° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
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| 5 | 16270 | 00000 | 27661 | 99992 | 56054 | 69971 | 55 |
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| 7 | 30882 | 00000 | 28977 | 99992 | 56743 | 99970 | 53 |
| 8 | 36682 | 00000 | 29621 | 99992 | 57084 | 99970 | 52 |
| 9 | 41797 | 00000 | 30255 | 99991 | 57421 | 99969 | 51 |
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| 14 | 60985 | 00000 | 33292 | 99990 | 59072 | 99967 | 46 |
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| 18 | 71900 | 99999 | 35578 | 99989 | 60349 | 99965 | 42 |
| 19 | 74248 | 99999 | 36131 | 99989 | 60662 | 99964 | 41 |
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| 21 | 78594 | 99999 | 37217 | 99988 | 61282 | 99963 | 39 |
| 22 | 80615 | 99999 | 37750 | 99988 | 61589 | 99963 | 38 |
| 23 | 82545 | 99999 | 38276 | 99987 | 61894 | 99962 | 37 |
| 24 | 84393 | 99999 | 38796 | 99987 | 62196 | 99962 | 36 |
| 25 | 86166 | 99999 | 39310 | 99987 | 62497 | 99961 | 35 |
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| 27 | 89509 | 99999 | 40320 | 99986 | 63091 | 99960 | 33 |
| 28 | 91088 | 99999 | 40816 | 99986 | 63385 | 99960 | 32 |
| 29 | 92612 | 99998 | 41307 | 99985 | 63678 | 99959 | 31 |
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| 31 | 95508 | 99998 | 42272 | 99985 | 64256 | 99958 | 29 |
| 32 | 96887 | 99998 | 42746 | 99984 | 64543 | 99958 | 28 |
| 33 | 98223 | 99998 | 43216 | 99984 | 64827 | 99957 | 27 |
| 34 | 99520 | 99998 | 43680 | 99984 | 65110 | 99956 | 26 |
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| 37 | 03192 | 99997 | 45044 | 99983 | 65947 | 99955 | 23 |
| 38 | 04350 | 99997 | 45489 | 99982 | 66223 | 99954 | 22 |
| 39 | 05478 | 99997 | 45930 | 99982 | 66497 | 99954 | 21 |
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| 41 | 07650 | 99997 | 46799 | 99981 | 67039 | 99952 | 19 |
| 42 | 08696 | 99997 | 47226 | 99981 | 67308 | 99952 | 18 |
| 43 | 09718 | 99997 | 47650 | 99981 | 67575 | 99951 | 17 |
| 44 | 10717 | 99996 | 48069 | 99980 | 67841 | 99951 | 16 |
| 45 | 11693 | 99996 | 48485 | 99980 | 68104 | 99950 | 15 |
| 46 | 12647 | 99996 | 48896 | 99979 | 68367 | 99949 | 14 |
| 47 | 13581 | 99996 | 49304 | 99979 | 68627 | 99949 | 13 |
| 48 | 14495 | 99996 | 49708 | 99979 | 68886 | 99948 | 12 |
| 49 | 15391 | 99996 | 50108 | 99978 | 69144 | 99948 | 11 |
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| 51 | 17128 | 99995 | 50897 | 99977 | 69654 | 99946 | 9 |
| 52 | 17971 | 99995 | 51287 | 99977 | 69907 | 99946 | 8 |
| 53 | 18798 | 99995 | 51673 | 99977 | 70159 | 99945 | 7 |
| 54 | 19610 | 99995 | 52055 | 99976 | 70409 | 99944 | 6 |
| 55 | 20407 | 99994 | 52434 | 99976 | 70658 | 99944 | 5 |
| 56 | 21189 | 99994 | 52810 | 99975 | 70905 | 99943 | 4 |
| 57 | 21958 | 99994 | 53183 | 99975 | 71151 | 99942 | 3 |
| 58 | 22713 | 99994 | 53552 | 99974 | 71395 | 99942 | 2 |
| 59 | 23456 | 99994 | 53919 | 99974 | 71638 | 99941 | 1 |
| 60 | 24186 | 99993 | 54282 | 99974 | 71880 | 99940 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 89° | | 88° | | 87° | | |

| ′ | 3° Sine | 3° Cosine | 4° Sine | 4° Cosine | 5° Sine | 5° Cosine | ′ |
|---|---|---|---|---|---|---|---|
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| 3 | 72597 | 99938 | 84897 | 99891 | 94461 | 99831 | 57 |
| 4 | 72834 | 99938 | 85075 | 99891 | 94603 | 99830 | 56 |
| 5 | 73069 | 99937 | 85252 | 99890 | 94746 | 99829 | 55 |
| 6 | 73303 | 99936 | 85429 | 99889 | 94887 | 99828 | 54 |
| 7 | 73535 | 99936 | 85605 | 99888 | 95029 | 99827 | 53 |
| 8 | 73767 | 99935 | 85780 | 99887 | 95170 | 99825 | 52 |
| 9 | 73997 | 99934 | 85955 | 99886 | 95310 | 99824 | 51 |
| 10 | 8.74226 | 9.99934 | 8.86128 | 9.99885 | 8.95450 | 9.99823 | 50 |
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| 13 | 74906 | 99932 | 86645 | 99882 | 95867 | 99820 | 47 |
| 14 | 75130 | 99931 | 86816 | 99881 | 96005 | 99819 | 46 |
| 15 | 75353 | 99930 | 86987 | 99880 | 96143 | 99817 | 45 |
| 16 | 75575 | 99929 | 87156 | 99879 | 96280 | 99816 | 44 |
| 17 | 75795 | 99929 | 87325 | 99879 | 96417 | 99815 | 43 |
| 18 | 76015 | 99928 | 87494 | 99878 | 96553 | 99814 | 42 |
| 19 | 76234 | 99927 | 87661 | 99877 | 96689 | 99813 | 41 |
| 20 | 8.76451 | 9.99926 | 8.87829 | 9.99876 | 8.96825 | 9.99812 | 40 |
| 21 | 76667 | 99926 | 87995 | 99875 | 96960 | 99810 | 39 |
| 22 | 76883 | 99925 | 88161 | 99874 | 97095 | 99809 | 38 |
| 23 | 77097 | 99924 | 88326 | 99873 | 97229 | 99808 | 37 |
| 24 | 77310 | 99923 | 88490 | 99872 | 97363 | 99807 | 36 |
| 25 | 77522 | 99923 | 88654 | 99871 | 97496 | 99806 | 35 |
| 26 | 77733 | 99922 | 88817 | 99870 | 97629 | 99804 | 34 |
| 27 | 77943 | 99921 | 88980 | 99869 | 97762 | 99803 | 33 |
| 28 | 78152 | 99920 | 89142 | 99868 | 97894 | 99802 | 32 |
| 29 | 78360 | 99920 | 89304 | 99867 | 98026 | 99801 | 31 |
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| 31 | 78774 | 99918 | 89625 | 99865 | 98288 | 99798 | 29 |
| 32 | 78979 | 99917 | 89784 | 99864 | 98419 | 99797 | 28 |
| 33 | 79183 | 99917 | 89943 | 99863 | 98549 | 99796 | 27 |
| 34 | 79386 | 99916 | 90102 | 99862 | 98679 | 99795 | 26 |
| 35 | 79588 | 99915 | 90260 | 99861 | 98808 | 99793 | 25 |
| 36 | 79789 | 99914 | 90417 | 99860 | 98937 | 99792 | 24 |
| 37 | 79990 | 99913 | 90574 | 99859 | 99066 | 99791 | 23 |
| 38 | 80189 | 99913 | 90730 | 99858 | 99194 | 99790 | 22 |
| 39 | 80388 | 99912 | 90885 | 99857 | 99322 | 99788 | 21 |
| 40 | 8.80585 | 9.99911 | 8.91040 | 9.99856 | 8.99450 | 9.99787 | 20 |
| 41 | 80782 | 99910 | 91195 | 99855 | 99577 | 99786 | 19 |
| 42 | 80978 | 99909 | 91349 | 99854 | 99704 | 99785 | 18 |
| 43 | 81173 | 99909 | 91502 | 99853 | 99830 | 99783 | 17 |
| 44 | 81367 | 99908 | 91655 | 99852 | 99956 | 99782 | 16 |
| 45 | 81560 | 99907 | 91807 | 99851 | 9.00082 | 99781 | 15 |
| 46 | 81752 | 99906 | 91959 | 99850 | 00207 | 99780 | 14 |
| 47 | 81944 | 99905 | 92110 | 99848 | 00332 | 99778 | 13 |
| 48 | 82134 | 99904 | 92261 | 99847 | 00456 | 99777 | 12 |
| 49 | 82324 | 99904 | 92411 | 99846 | 00581 | 99776 | 11 |
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| 51 | 82701 | 99902 | 92710 | 99844 | 00828 | 99773 | 9 |
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| 53 | 83075 | 99900 | 93007 | 99842 | 01074 | 99771 | 7 |
| 54 | 83261 | 99899 | 93154 | 99841 | 01196 | 99769 | 6 |
| 55 | 83446 | 99898 | 93301 | 99840 | 01318 | 99768 | 5 |
| 56 | 83630 | 99898 | 93448 | 99839 | 01440 | 99767 | 4 |
| 57 | 83813 | 99897 | 93594 | 99838 | 01561 | 99765 | 3 |
| 58 | 83996 | 99896 | 93740 | 99837 | 01682 | 99764 | 2 |
| 59 | 84177 | 99895 | 93885 | 99836 | 01803 | 99763 | 1 |
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| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
|  | 86° |  | 85° |  | 84° |  |  |

| ′ | 6° |  | 7° |  | 8° |  | ′ |
|---|---|---|---|---|---|---|---|
|  | Sine | Cosine | Sine | Cosine | Sine | Cosine |  |
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| 2 | 02163 | 99759 | 08795 | 99672 | 14535 | 99572 | 58 |
| 3 | 02283 | 99757 | 08897 | 99670 | 14624 | 99570 | 57 |
| 4 | 02402 | 99756 | 08999 | 99669 | 14714 | 99568 | 56 |
| 5 | 02520 | 99755 | 09101 | 99667 | 14803 | 99566 | 55 |
| 6 | 02639 | 99753 | 09202 | 99666 | 14891 | 99565 | 54 |
| 7 | 02757 | 99752 | 09304 | 99664 | 14980 | 99563 | 53 |
| 8 | 02874 | 99751 | 09405 | 99663 | 15069 | 99561 | 52 |
| 9 | 02992 | 99749 | 09506 | 99661 | 15157 | 99559 | 51 |
| 10 | 9.03109 | 9.99748 | 9.09606 | 9.99659 | 9.15245 | 9.99557 | 50 |
| 11 | 03226 | 99747 | 09707 | 99658 | 15333 | 99556 | 49 |
| 12 | 03342 | 99745 | 09807 | 99656 | 15421 | 99554 | 48 |
| 13 | 03458 | 99744 | 09907 | 99655 | 15508 | 99552 | 47 |
| 14 | 03574 | 99742 | 10006 | 99653 | 15596 | 99550 | 46 |
| 15 | 03690 | 99741 | 10106 | 99651 | 15683 | 99548 | 45 |
| 16 | 03805 | 99740 | 10205 | 99650 | 15770 | 99546 | 44 |
| 17 | 03920 | 99738 | 10304 | 99648 | 15857 | 99545 | 43 |
| 18 | 04034 | 99737 | 10402 | 99647 | 15944 | 99543 | 42 |
| 19 | 04149 | 99736 | 10501 | 99645 | 16030 | 99541 | 41 |
| 20 | 9.04262 | 9.99734 | 9.10599 | 9.99643 | 9.16116 | 9.99539 | 40 |
| 21 | 04376 | 99733 | 10697 | 99642 | 16203 | 99537 | 39 |
| 22 | 04490 | 99731 | 10795 | 99640 | 16289 | 99535 | 38 |
| 23 | 04603 | 99730 | 10893 | 99628 | 16374 | 99533 | 37 |
| 24 | 04715 | 99728 | 10990 | 99637 | 16460 | 99532 | 36 |
| 25 | 04828 | 99727 | 11087 | 99635 | 16545 | 99530 | 35 |
| 26 | 04940 | 99726 | 11184 | 99633 | 16631 | 99528 | 34 |
| 27 | 05052 | 99724 | 11281 | 99632 | 16716 | 99526 | 33 |
| 28 | 05164 | 99723 | 11377 | 99630 | 16801 | 99524 | 32 |
| 29 | 05275 | 99721 | 11474 | 99629 | 16886 | 99522 | 31 |
| 30 | 9.05386 | 9.99720 | 9.11570 | 9.99627 | 9.16970 | 9.99520 | 30 |
| 31 | 05497 | 99718 | 11666 | 99625 | 17055 | 99518 | 29 |
| 32 | 05607 | 99717 | 11761 | 99624 | 17139 | 99517 | 28 |
| 33 | 05717 | 99716 | 11857 | 99622 | 17223 | 99515 | 27 |
| 34 | 05827 | 99714 | 11952 | 99620 | 17307 | 99513 | 26 |
| 35 | 05937 | 99713 | 12047 | 99618 | 17391 | 99511 | 25 |
| 36 | 06046 | 99711 | 12142 | 99617 | 17474 | 99509 | 24 |
| 37 | 06155 | 99710 | 12236 | 99615 | 17558 | 99507 | 23 |
| 38 | 06264 | 99708 | 12331 | 99613 | 17641 | 99505 | 22 |
| 39 | 06372 | 99707 | 12425 | 99612 | 17724 | 99503 | 21 |
| 40 | 9.06481 | 9.99705 | 9.12519 | 9.99610 | 9.17807 | 9.99501 | 20 |
| 41 | 06589 | 99704 | 12612 | 99608 | 17890 | 99499 | 19 |
| 42 | 06696 | 99702 | 12706 | 99607 | 17973 | 99497 | 18 |
| 43 | 06804 | 99701 | 12799 | 99605 | 18055 | 99495 | 17 |
| 44 | 06911 | 99699 | 12892 | 99603 | 18137 | 99494 | 16 |
| 45 | 07018 | 99698 | 12985 | 99601 | 18220 | 99492 | 15 |
| 46 | 07124 | 99696 | 13078 | 99600 | 18302 | 99490 | 14 |
| 47 | 07231 | 99695 | 13171 | 99598 | 18383 | 99488 | 13 |
| 48 | 07337 | 99693 | 13263 | 99596 | 18465 | 99486 | 12 |
| 49 | 07442 | 99692 | 13355 | 99595 | 18547 | 99484 | 11 |
| 50 | 9.07548 | 9.99690 | 9.13447 | 9.99593 | 9.18628 | 9.99482 | 10 |
| 51 | 07653 | 99689 | 13539 | 99591 | 18709 | 99480 | 9 |
| 52 | 07758 | 99687 | 13630 | 99589 | 18790 | 99478 | 8 |
| 53 | 07863 | 99686 | 13722 | 99588 | 18871 | 99476 | 7 |
| 54 | 07968 | 99684 | 13813 | 99586 | 18952 | 99474 | 6 |
| 55 | 08072 | 99683 | 13904 | 99584 | 19033 | 99472 | 5 |
| 56 | 08176 | 99681 | 13994 | 99582 | 19113 | 99470 | 4 |
| 57 | 08280 | 99680 | 14085 | 99581 | 19193 | 99468 | 3 |
| 58 | 08383 | 99678 | 14175 | 99579 | 19273 | 99466 | 2 |
| 59 | 08486 | 99677 | 14266 | 99577 | 19353 | 99464 | 1 |
| 60 | 08589 | 99675 | 14356 | 99575 | 19433 | 99462 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
|  | 83° |  | 82° |  | 81° |  |  |

| ′ | 9° | | 10° | | 11° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.19483 | 9.99462 | 9.23967 | 9.99335 | 9.28060 | 9.99195 | 60 |
| 1 | 19513 | 99460 | 24039 | 99333 | 28125 | 99192 | 59 |
| 2 | 19592 | 99458 | 24110 | 99331 | 28190 | 99190 | 58 |
| 3 | 19672 | 99456 | 24181 | 99328 | 28254 | 99187 | 57 |
| 4 | 19751 | 99454 | 24253 | 99326 | 28319 | 99185 | 56 |
| 5 | 19830 | 99452 | 24324 | 99324 | 28384 | 99182 | 55 |
| 6 | 19909 | 99450 | 24395 | 99322 | 28448 | 99180 | 54 |
| 7 | 19988 | 99448 | 24466 | 99319 | 28512 | 99177 | 53 |
| 8 | 20067 | 99446 | 24536 | 99317 | 28577 | 99175 | 52 |
| 9 | 20145 | 99444 | 24607 | 99315 | 28641 | 99172 | 51 |
| 10 | 9.20223 | 9.99442 | 9.24677 | 9.99313 | 9.28705 | 9.99170 | 50 |
| 11 | 20302 | 99440 | 24748 | 99310 | 28769 | 99167 | 49 |
| 12 | 20380 | 99438 | 24818 | 99308 | 28833 | 99165 | 48 |
| 13 | 20458 | 99436 | 24888 | 99306 | 28896 | 99162 | 47 |
| 14 | 20535 | 99434 | 24958 | 99304 | 28960 | 99160 | 46 |
| 15 | 20613 | 99432 | 25028 | 99301 | 29024 | 99157 | 45 |
| 16 | 20691 | 99429 | 25098 | 99299 | 29087 | 99155 | 44 |
| 17 | 20768 | 99427 | 25168 | 99297 | 29150 | 99152 | 43 |
| 18 | 20845 | 99425 | 25237 | 99294 | 29214 | 99150 | 42 |
| 19 | 20922 | 99423 | 25307 | 99292 | 29277 | 99147 | 41 |
| 20 | 9.20999 | 9.99421 | 9.25376 | 9.99290 | 9.29340 | 9.99145 | 40 |
| 21 | 21076 | 99419 | 25445 | 99288 | 29403 | 99142 | 39 |
| 22 | 21153 | 99417 | 25514 | 99285 | 29466 | 99140 | 38 |
| 23 | 21229 | 99415 | 25583 | 99283 | 29529 | 99137 | 37 |
| 24 | 21306 | 99413 | 25652 | 99281 | 29591 | 99135 | 36 |
| 25 | 21382 | 99411 | 25721 | 99278 | 29654 | 99132 | 35 |
| 23 | 21458 | 99409 | 25790 | 99276 | 29716 | 99130 | 34 |
| 27 | 21534 | 99407 | 25858 | 99274 | 29779 | 99127 | 33 |
| 28 | 21610 | 99404 | 25927 | 99271 | 29841 | 99124 | 32 |
| 29 | 21685 | 99402 | 25995 | 99269 | 29903 | 99122 | 31 |
| 30 | 9.21761 | 9.99400 | 9.26063 | 9.99267 | 9.29966 | 9.99119 | 30 |
| 31 | 21836 | 99398 | 26131 | 99264 | 30028 | 99117 | 29 |
| 32 | 21912 | 99396 | 26199 | 99262 | 30090 | 99114 | 28 |
| 33 | 21987 | 99394 | 26267 | 99260 | 30151 | 99112 | 27 |
| 34 | 22062 | 99392 | 26335 | 99257 | 30213 | 99109 | 26 |
| 35 | 22137 | 99390 | 26403 | 99255 | 30275 | 99106 | 25 |
| 36 | 22211 | 99388 | 26470 | 99252 | 30336 | 99104 | 24 |
| 37 | 22286 | 99385 | 26538 | 99250 | 30398 | 99001 | 23 |
| 38 | 22361 | 99383 | 26605 | 99248 | 30459 | 99099 | 22 |
| 39 | 22435 | 99381 | 26672 | 99245 | 30521 | 99096 | 21 |
| 40 | 9.22509 | 9.99379 | 9.26739 | 9.99243 | 9.30582 | 9.99098 | 20 |
| 41 | 22583 | 99377 | 26806 | 99241 | 30643 | 99091 | 19 |
| 42 | 22657 | 99375 | 26873 | 99238 | 30704 | 99088 | 18 |
| 43 | 22731 | 99372 | 26940 | 99236 | 30765 | 99086 | 17 |
| 44 | 22805 | 99370 | 27007 | 99233 | 30826 | 99083 | 16 |
| 45 | 22878 | 99368 | 27073 | 90231 | 30887 | 99080 | 15 |
| 46 | 22952 | 99366 | 27140 | 99229 | 30947 | 99078 | 14 |
| 47 | 23025 | 99364 | 27206 | 99226 | 31008 | 99075 | 13 |
| 48 | 23098 | 99362 | 27273 | 99224 | 31068 | 99072 | 12 |
| 49 | 23171 | 99359 | 27339 | 99221 | 31129 | 99070 | 11 |
| 50 | 9.23244 | 9.99357 | 9.27405 | 9.99219 | 9.31189 | 9.99067 | 10 |
| 51 | 23317 | 99355 | 27471 | 99217 | 31250 | 99064 | 9 |
| 52 | 23390 | 99353 | 27537 | 99214 | 31310 | 99062 | 8 |
| 53 | 23462 | 99351 | 27602 | 99212 | 31370 | 99059 | 7 |
| 54 | 23535 | 99348 | 27668 | 99209 | 31430 | 99056 | 6 |
| 55 | 23607 | 99346 | 27734 | 99207 | 31490 | 99054 | 5 |
| 56 | 23679 | 99344 | 27799 | 99204 | 31549 | 99051 | 4 |
| 57 | 23752 | 99342 | 27864 | 99202 | 31609 | 99048 | 3 |
| 58 | 23823 | 99340 | 27930 | 99200 | 31669 | 99046 | 2 |
| 59 | 23895 | 99337 | 27995 | 99197 | 31728 | 99043 | 1 |
| 60 | 23967 | 99335 | 28060 | 99195 | 31788 | 99040 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 80° | | 79° | | 78° | | |

## TABLE VII.—LOGARITHMIC SINES AND COSINES.

| ′ | 12° | | 13° | | 14° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.31788 | 9.99040 | 9.35209 | 9.98872 | 9.38368 | 9.98690 | 60 |
| 1 | 31847 | 99038 | 35263 | 98869 | 38418 | 98687 | 59 |
| 2 | 31907 | 99035 | 35318 | 98867 | 38469 | 98684 | 58 |
| 3 | 31966 | 99032 | 35373 | 98864 | 38519 | 98681 | 57 |
| 4 | 32025 | 99030 | 35427 | 98861 | 38570 | 98678 | 56 |
| 5 | 32084 | 99027 | 35481 | 98858 | 38620 | 98675 | 55 |
| 6 | 32143 | 99024 | 35536 | 98855 | 38670 | 98671 | 54 |
| 7 | 32202 | 99022 | 35590 | 98852 | 38721 | 98668 | 53 |
| 8 | 32261 | 99019 | 35644 | 98849 | 38771 | 98665 | 52 |
| 9 | 32319 | 99016 | 35698 | 98846 | 38821 | 98662 | 51 |
| 10 | 9.32378 | 9.99013 | 9.35752 | 9.98843 | 9.38871 | 9.98659 | 50 |
| 11 | 32437 | 99011 | 35806 | 98840 | 38921 | 98656 | 49 |
| 12 | 32495 | 99008 | 35860 | 98837 | 38971 | 98652 | 48 |
| 13 | 32553 | 99005 | 35914 | 98834 | 39021 | 98649 | 47 |
| 14 | 32612 | 99002 | 35968 | 98831 | 39071 | 98646 | 46 |
| 15 | 32670 | 99000 | 36022 | 98828 | 39121 | 98643 | 45 |
| 16 | 32728 | 98997 | 36075 | 98825 | 39170 | 98640 | 44 |
| 17 | 32786 | 98994 | 36129 | 98822 | 39220 | 98636 | 43 |
| 18 | 32844 | 98991 | 36182 | 98819 | 39270 | 98633 | 42 |
| 19 | 32902 | 98989 | 36236 | 98816 | 39319 | 98630 | 41 |
| 20 | 9.32960 | 9.98986 | 9.36289 | 9.98813 | 9.39369 | 9.98627 | 40 |
| 21 | 33018 | 98983 | 36342 | 98810 | 39418 | 98623 | 39 |
| 22 | 33075 | 98980 | 36395 | 98807 | 39467 | 98620 | 38 |
| 23 | 33133 | 98978 | 36449 | 98804 | 39517 | 98617 | 37 |
| 24 | 33190 | 98975 | 36502 | 98801 | 39566 | 98614 | 36 |
| 25 | 33248 | 98972 | 36555 | 98798 | 39615 | 98610 | 35 |
| 26 | 33305 | 98969 | 36608 | 98795 | 39664 | 98607 | 34 |
| 27 | 33362 | 98967 | 36660 | 98792 | 39713 | 98604 | 33 |
| 28 | 33420 | 98964 | 36713 | 98789 | 39762 | 98601 | 32 |
| 29 | 33477 | 98961 | 36766 | 98786 | 39811 | 98597 | 31 |
| 30 | 9.33534 | 9.98958 | 9.36819 | 9.98783 | 9.39860 | 9.98594 | 30 |
| 31 | 33591 | 98955 | 36871 | 98780 | 39909 | 98591 | 29 |
| 32 | 33647 | 98953 | 36924 | 98777 | 39958 | 98588 | 28 |
| 33 | 33704 | 98950 | 36976 | 98774 | 40006 | 98584 | 27 |
| 34 | 33761 | 98947 | 37028 | 98771 | 40055 | 98581 | 26 |
| 35 | 33818 | 98944 | 37081 | 98768 | 40103 | 98578 | 25 |
| 36 | 33874 | 98941 | 37133 | 98765 | 40152 | 98574 | 24 |
| 37 | 33931 | 98938 | 37185 | 98762 | 40200 | 98571 | 23 |
| 38 | 33987 | 98936 | 37237 | 98759 | 40249 | 98568 | 22 |
| 39 | 34043 | 98933 | 37289 | 98756 | 40297 | 98565 | 21 |
| 40 | 9.34100 | 9.98930 | 9.37341 | 9.98753 | 9.40346 | 9.98561 | 20 |
| 41 | 34156 | 98927 | 37393 | 98750 | 40394 | 98558 | 19 |
| 42 | 34212 | 98924 | 37445 | 98746 | 40442 | 98555 | 18 |
| 43 | 34268 | 98921 | 37497 | 98743 | 40490 | 98551 | 17 |
| 44 | 34324 | 98919 | 37549 | 98740 | 40538 | 98548 | 16 |
| 45 | 34380 | 98916 | 37600 | 98737 | 40586 | 98545 | 15 |
| 46 | 34436 | 98913 | 37652 | 98734 | 40634 | 98541 | 14 |
| 47 | 34491 | 98910 | 37703 | 98731 | 40682 | 98538 | 13 |
| 48 | 34547 | 98907 | 37755 | 98728 | 40730 | 98535 | 12 |
| 49 | 34602 | 98904 | 37806 | 98725 | 40778 | 98531 | 11 |
| 50 | 9.34658 | 9.98901 | 9.37858 | 9.98722 | 9.40825 | 9.98528 | 10 |
| 51 | 34713 | 98898 | 37909 | 98719 | 40873 | 98525 | 9 |
| 52 | 34769 | 98896 | 37960 | 98715 | 40921 | 98521 | 8 |
| 53 | 34824 | 98893 | 38011 | 98712 | 40968 | 98518 | 7 |
| 54 | 34879 | 98890 | 38062 | 98709 | 41016 | 98515 | 6 |
| 55 | 34934 | 98887 | 38113 | 98706 | 41063 | 98511 | 5 |
| 56 | 34989 | 98884 | 38164 | 98703 | 41111 | 98508 | 4 |
| 57 | 35044 | 98881 | 38215 | 98700 | 41158 | 98505 | 3 |
| 58 | 35099 | 98878 | 38266 | 98697 | 41205 | 98501 | 2 |
| 59 | 35154 | 98875 | 38317 | 98694 | 41252 | 98498 | 1 |
| 60 | 35209 | 98872 | 38368 | 98690 | 41300 | 98494 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 77° | | 76° | | 75° | | |

| ′ | 15° | | 16° | | 17° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.41300 | 9.98494 | 9.44034 | 9.98284 | 9.46594 | 9.98060 | 60 |
| 1 | 41347 | 98491 | 44078 | 98281 | 46635 | 98056 | 59 |
| 2 | 41394 | 98488 | 44122 | 98277 | 46676 | 98052 | 58 |
| 3 | 41441 | 98484 | 44166 | 98273 | 46717 | 98048 | 57 |
| 4 | 41488 | 98481 | 44210 | 98270 | 46758 | 98044 | 56 |
| 5 | 41535 | 98477 | 44253 | 98266 | 46800 | 98040 | 55 |
| 6 | 41582 | 98474 | 44297 | 98262 | 46841 | 98036 | 54 |
| 7 | 41628 | 98471 | 44341 | 98259 | 46882 | 98032 | 53 |
| 8 | 41675 | 98467 | 44385 | 98255 | 46923 | 98029 | 52 |
| 9 | 41722 | 98464 | 44428 | 98251 | 46964 | 98025 | 51 |
| 10 | 9.41768 | 9.98460 | 9.44472 | 9.98248 | 9.47005 | 9.98021 | 50 |
| 11 | 41815 | 98457 | 44516 | 98244 | 47045 | 98017 | 49 |
| 12 | 41861 | 98453 | 44559 | 98240 | 47086 | 98013 | 48 |
| 13 | 41908 | 98450 | 44602 | 98237 | 47127 | 98009 | 47 |
| 14 | 41954 | 98447 | 44646 | 98233 | 47168 | 98005 | 46 |
| 15 | 42001 | 98443 | 44689 | 98229 | 47209 | 98001 | 45 |
| 16 | 42047 | 98440 | 44733 | 98226 | 47249 | 97997 | 44 |
| 17 | 42093 | 98436 | 44776 | 98222 | 47290 | 97993 | 43 |
| 18 | 42140 | 98433 | 44819 | 98218 | 47330 | 97989 | 42 |
| 19 | 42186 | 98429 | 44862 | 98215 | 47371 | 97986 | 41 |
| 20 | 9.42232 | 9.98426 | 9.44905 | 9.98211 | 9.47411 | 9.97982 | 40 |
| 21 | 42278 | 98422 | 44948 | 98207 | 47452 | 97978 | 39 |
| 22 | 42324 | 98419 | 44992 | 98204 | 47492 | 97974 | 38 |
| 23 | 42370 | 98415 | 45035 | 98200 | 47533 | 97970 | 37 |
| 24 | 42416 | 98412 | 45077 | 98196 | 47573 | 97966 | 36 |
| 25 | 42461 | 98409 | 45120 | 98192 | 47613 | 97962 | 35 |
| 26 | 42507 | 98405 | 45163 | 98189 | 47654 | 97958 | 34 |
| 27 | 42553 | 98402 | 45206 | 98185 | 47694 | 97954 | 33 |
| 28 | 42599 | 98398 | 45249 | 98181 | 47734 | 97950 | 32 |
| 29 | 42644 | 98395 | 45292 | 98177 | 47774 | 97946 | 31 |
| 30 | 9.42690 | 9.98391 | 9.45334 | 9.98174 | 9.47814 | 9.97942 | 30 |
| 31 | 42735 | 98388 | 45377 | 98170 | 47854 | 97938 | 29 |
| 32 | 42781 | 98384 | 45419 | 98166 | 47894 | 97934 | 28 |
| 33 | 42826 | 98381 | 45462 | 98162 | 47934 | 97930 | 27 |
| 34 | 42872 | 98377 | 45504 | 93159 | 47974 | 97926 | 26 |
| 35 | 42917 | 98373 | 45547 | 98155 | 48014 | 97922 | 25 |
| 36 | 42962 | 98370 | 45589 | 98151 | 48054 | 97918 | 24 |
| 37 | 43008 | 98366 | 45632 | 98147 | 48094 | 97914 | 23 |
| 38 | 43053 | 98363 | 45674 | 98144 | 48133 | 97910 | 22 |
| 39 | 43098 | 98359 | 45716 | 98140 | 48173 | 97906 | 21 |
| 40 | 9.43143 | 9.98356 | 9.45758 | 9.98136 | 9.48218 | 9.97902 | 20 |
| 41 | 43188 | 98352 | 45801 | 98132 | 48252 | 97898 | 19 |
| 42 | 43233 | 98349 | 45843 | 98129 | 48292 | 97894 | 18 |
| 43 | 43278 | 98345 | 45885 | 98125 | 48332 | 97890 | 17 |
| 44 | 43323 | 98342 | 45927 | 98121 | 48371 | 97886 | 16 |
| 45 | 43367 | 98338 | 45969 | 98117 | 48411 | 97882 | 15 |
| 46 | 43412 | 98334 | 46011 | 98113 | 48450 | 97878 | 14 |
| 47 | 43457 | 98331 | 46053 | 98110 | 48490 | 97874 | 13 |
| 48 | 43502 | 98327 | 46095 | 98106 | 48529 | 97870 | 12 |
| 49 | 43546 | 98324 | 46136 | 98102 | 48568 | 97866 | 11 |
| 50 | 9.43591 | 9.98320 | 9.46178 | 9.98098 | 9.48607 | 9.97861 | 10 |
| 51 | 43635 | 98317 | 46220 | 98094 | 48647 | 97857 | 9 |
| 52 | 43680 | 98313 | 46262 | 98090 | 48686 | 97853 | 8 |
| 53 | 43724 | 98309 | 46303 | 98087 | 48725 | 97849 | 7 |
| 54 | 43769 | 98306 | 46345 | 98083 | 48764 | 97845 | 6 |
| 55 | 43813 | 98302 | 46386 | 98079 | 48803 | 97841 | 5 |
| 56 | 43857 | 98299 | 46428 | 98075 | 48842 | 97837 | 4 |
| 57 | 43901 | 98295 | 46469 | 98071 | 48881 | 97833 | 3 |
| 58 | 43946 | 98291 | 46511 | 98067 | 48920 | 97829 | 2 |
| 59 | 43990 | 98288 | 46552 | 98063 | 48959 | 97825 | 1 |
| 60 | 44034 | 98284 | 46594 | 98060 | 48998 | 97821 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 74° | | 73° | | 72° | | |

| ′ | 18° | | 19° | | 20° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.48998 | 9.97821 | 9.51264 | 9.97567 | 9.53405 | 9.97299 | 60 |
| 1 | 49037 | 97817 | 51301 | 97563 | 53440 | 97294 | 59 |
| 2 | 49076 | 97812 | 51338 | 97558 | 53475 | 97289 | 58 |
| 3 | 49115 | 97808 | 51374 | 97554 | 53509 | 97285 | 57 |
| 4 | 49153 | 97804 | 51411 | 97550 | 53544 | 97280 | 56 |
| 5 | 49192 | 97800 | 51447 | 97545 | 53578 | 97276 | 55 |
| 6 | 49231 | 97796 | 51484 | 97541 | 53613 | 97271 | 54 |
| 7 | 49269 | 97792 | 51520 | 97536 | 53647 | 97266 | 53 |
| 8 | 49308 | 97788 | 51557 | 97532 | 53682 | 97262 | 52 |
| 9 | 49347 | 97784 | 51593 | 97528 | 53716 | 97257 | 51 |
| 10 | 9.49385 | 9.97779 | 9.51629 | 9.97523 | 9.53751 | 9.97252 | 50 |
| 11 | 49424 | 97775 | 51666 | 97519 | 53785 | 97248 | 49 |
| 12 | 49462 | 97771 | 51702 | 97515 | 53819 | 97243 | 48 |
| 13 | 49500 | 97767 | 51738 | 97510 | 53854 | 97238 | 47 |
| 14 | 49539 | 97763 | 51774 | 97506 | 53888 | 97234 | 46 |
| 15 | 49577 | 97759 | 51811 | 97501 | 53922 | 97229 | 45 |
| 16 | 49615 | 97754 | 51847 | 97497 | 53957 | 97224 | 44 |
| 17 | 49654 | 97750 | 51883 | 97492 | 53991 | 97220 | 43 |
| 18 | 49692 | 97746 | 51919 | 97488 | 54025 | 97215 | 42 |
| 19 | 49730 | 97742 | 51955 | 97484 | 54059 | 97210 | 41 |
| 20 | 9.49768 | 9.97738 | 9.51991 | 9.97479 | 9.54093 | 9.97206 | 40 |
| 21 | 49806 | 97734 | 52027 | 97475 | 54127 | 97201 | 39 |
| 22 | 49844 | 97729 | 52063 | 97470 | 54161 | 97196 | 38 |
| 23 | 49882 | 97725 | 52099 | 97466 | 54195 | 97192 | 37 |
| 24 | 49920 | 97721 | 52135 | 97461 | 54229 | 97187 | 36 |
| 25 | 49958 | 97717 | 52171 | 97457 | 54263 | 97182 | 35 |
| 26 | 49996 | 97713 | 52207 | 97453 | 54297 | 97178 | 34 |
| 27 | 50034 | 97708 | 52242 | 97448 | 54331 | 97173 | 33 |
| 28 | 50072 | 97704 | 52278 | 97444 | 54365 | 97168 | 32 |
| 29 | 50110 | 97700 | 52314 | 97439 | 54399 | 97163 | 31 |
| 30 | 9.50148 | 9.97696 | 9.52350 | 9.97435 | 9.54433 | 9.97159 | 30 |
| 31 | 50185 | 97691 | 52385 | 97430 | 54466 | 97154 | 29 |
| 32 | 50223 | 97687 | 52421 | 97426 | 54500 | 97149 | 28 |
| 33 | 50261 | 97683 | 52456 | 97421 | 54534 | 97145 | 27 |
| 34 | 50298 | 97679 | 52492 | 97417 | 54567 | 97140 | 26 |
| 35 | 50336 | 97674 | 52527 | 97412 | 54601 | 97135 | 25 |
| 36 | 50374 | 97670 | 52563 | 97408 | 54635 | 97130 | 24 |
| 37 | 50411 | 97666 | 52598 | 97403 | 54668 | 97126 | 23 |
| 38 | 50449 | 97662 | 52634 | 97399 | 54702 | 97121 | 22 |
| 39 | 50486 | 97657 | 52669 | 97394 | 54735 | 97116 | 21 |
| 40 | 9.50523 | 9.97653 | 9.52705 | 9.97390 | 9.54769 | 9.97111 | 20 |
| 41 | 50561 | 97649 | 52740 | 97385 | 54802 | 97107 | 19 |
| 42 | 50598 | 97645 | 52775 | 97381 | 54836 | 97102 | 18 |
| 43 | 50635 | 97640 | 52811 | 97376 | 54869 | 97097 | 17 |
| 44 | 50673 | 97636 | 52846 | 97372 | 54903 | 97092 | 16 |
| 45 | 50710 | 97632 | 52881 | 97367 | 54936 | 97087 | 15 |
| 46 | 50747 | 97628 | 52916 | 97363 | 54969 | 97083 | 14 |
| 47 | 50784 | 97623 | 52951 | 97358 | 55003 | 97078 | 13 |
| 48 | 50821 | 97619 | 52986 | 97353 | 55036 | 97073 | 12 |
| 49 | 50858 | 97615 | 53021 | 97349 | 55069 | 97068 | 11 |
| 50 | 9.50896 | 9.97610 | 9.53056 | 9.97344 | 9.55102 | 9.97063 | 10 |
| 51 | 50933 | 97606 | 53092 | 97340 | 55136 | 97059 | 9 |
| 52 | 50970 | 97602 | 53126 | 97335 | 55169 | 97054 | 8 |
| 53 | 51007 | 97597 | 53161 | 97331 | 55202 | 97049 | 7 |
| 54 | 51043 | 97593 | 53196 | 97326 | 55235 | 97044 | 6 |
| 55 | 51080 | 97589 | 53231 | 97322 | 55268 | 97039 | 5 |
| 56 | 51117 | 97584 | 53266 | 97317 | 55301 | 97035 | 4 |
| 57 | 51154 | 97580 | 53301 | 97312 | 55334 | 97030 | 3 |
| 58 | 51191 | 97576 | 53336 | 97308 | 55367 | 97025 | 2 |
| 59 | 51227 | 97571 | 53370 | 97303 | 55400 | 97020 | 1 |
| 60 | 51264 | 97567 | 53405 | 97299 | 55433 | 97015 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 71° | | 70° | | 69° | | |

| 21° | | 22° | | 23° | | ′ |
|---|---|---|---|---|---|---|
| Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 9.55433 | 9.97015 | 9.57358 | 9.96717 | 9.59188 | 9.96403 | 60 |
| 55466 | 97010 | 57389 | 96711 | 59218 | 96397 | 59 |
| 55499 | 97005 | 57420 | 96706 | 59247 | 96392 | 58 |
| 55532 | 97001 | 57451 | 96701 | 59277 | 96387 | 57 |
| 55564 | 96996 | 57482 | 96696 | 59307 | 96381 | 56 |
| 55597 | 96991 | 57514 | 96691 | 59336 | 96376 | 55 |
| 55630 | 96986 | 57545 | 96686 | 59366 | 96370 | 54 |
| 55663 | 96981 | 57576 | 96681 | 59396 | 96365 | 53 |
| 55695 | 96976 | 57607 | 96676 | 59425 | 96360 | 52 |
| 55728 | 96971 | 57638 | 96670 | 59455 | 96354 | 51 |
| 9.55761 | 9.96966 | 9.57669 | 9.96665 | 9.59484 | 9.96349 | 50 |
| 55793 | 96962 | 57700 | 96660 | 59514 | 96343 | 49 |
| 55826 | 96957 | 57731 | 96655 | 59543 | 96338 | 48 |
| 55858 | 96952 | 57762 | 96650 | 59573 | 96333 | 47 |
| 55891 | 96947 | 57793 | 96645 | 59602 | 96327 | 46 |
| 55923 | 96942 | 57824 | 96640 | 59632 | 96322 | 45 |
| 55956 | 96937 | 57855 | 96634 | 59661 | 96316 | 44 |
| 55988 | 96932 | 57885 | 96629 | 59690 | 96311 | 43 |
| 56021 | 96927 | 57916 | 96624 | 59720 | 96305 | 42 |
| 56053 | 96922 | 57947 | 96619 | 59749 | 96300 | 41 |
| 9.56085 | 9.96917 | 9.57978 | 9.96614 | 9.59778 | 9.96294 | 40 |
| 56118 | 96912 | 58008 | 96608 | 59808 | 96289 | 39 |
| 56150 | 96907 | 58039 | 96603 | 59837 | 96284 | 38 |
| 56182 | 96903 | 58070 | 96598 | 59866 | 96278 | 37 |
| 56215 | 96898 | 58101 | 96593 | 59895 | 96273 | 36 |
| 56247 | 96893 | 58131 | 96588 | 59924 | 96267 | 35 |
| 56279 | 96888 | 58162 | 96582 | 59954 | 96262 | 34 |
| 56311 | 96883 | 58192 | 96577 | 59983 | 96256 | 33 |
| 56343 | 96878 | 58223 | 96572 | 60012 | 96251 | 32 |
| 56375 | 96873 | 58253 | 96567 | 60041 | 96245 | 31 |
| 9.56408 | 9.96868 | 9.58284 | 9.96562 | 9.60070 | 9.96240 | 30 |
| 56440 | 96863 | 58314 | 96556 | 60099 | 96234 | 29 |
| 56472 | 96858 | 58345 | 96551 | 60128 | 96229 | 28 |
| 56504 | 96853 | 58375 | 96546 | 60157 | 96223 | 27 |
| 56536 | 96848 | 58406 | 96541 | 60186 | 96218 | 26 |
| 56568 | 96843 | 58436 | 96535 | 60215 | 96212 | 25 |
| 56599 | 96838 | 58467 | 96530 | 60244 | 96207 | 24 |
| 56631 | 96833 | 58497 | 96525 | 60273 | 96201 | 23 |
| 56663 | 96828 | 58527 | 96520 | 60302 | 96196 | 22 |
| 56695 | 96823 | 58557 | 96514 | 60331 | 96190 | 21 |
| 9.56727 | 9.96818 | 9.58588 | 9.96509 | 9.60359 | 9.96185 | 20 |
| 56759 | 96813 | 58618 | 96504 | 60388 | 96179 | 19 |
| 56790 | 96808 | 58648 | 96498 | 60417 | 96174 | 18 |
| 56822 | 96803 | 58678 | 96493 | 60446 | 96168 | 17 |
| 56854 | 96798 | 58709 | 96488 | 60474 | 96162 | 16 |
| 56886 | 96793 | 58739 | 96483 | 60503 | 96157 | 15 |
| 56917 | 96788 | 58769 | 96477 | 60532 | 96151 | 14 |
| 56949 | 96783 | 58799 | 96472 | 60561 | 96146 | 13 |
| 56980 | 96778 | 58829 | 96467 | 60589 | 96140 | 12 |
| 57012 | 96772 | 58859 | 96461 | 60618 | 96135 | 11 |
| 9.57044 | 9.96767 | 9.58889 | 9.96456 | 9.60646 | 9.96129 | 10 |
| 57075 | 96762 | 58919 | 96451 | 60675 | 96123 | 9 |
| 57107 | 96757 | 58949 | 96445 | 60704 | 96118 | 8 |
| 57138 | 96752 | 58979 | 96440 | 60732 | 96112 | 7 |
| 57169 | 96747 | 59009 | 96435 | 60761 | 96107 | 6 |
| 57201 | 96742 | 59039 | 96429 | 60789 | 96101 | 5 |
| 57232 | 96737 | 59069 | 96424 | 60818 | 96095 | 4 |
| 57264 | 96732 | 59098 | 96419 | 60846 | 96090 | 3 |
| 57295 | 96727 | 59128 | 96413 | 60875 | 96084 | 2 |
| 57326 | 96722 | 59158 | 96408 | 60903 | 96079 | 1 |
| 57358 | 96717 | 59188 | 96403 | 60931 | 96073 | 0 |
| Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| 68° | | 67° | | 66° | | |

| ′ | 24° | | 25° | | 26° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.60931 | 9.96073 | 9.62595 | 9.95728 | 9.64184 | 9.95366 | 60 |
| 1 | 60960 | 96067 | 62622 | 95722 | 64210 | 95360 | 59 |
| 2 | 60988 | 96062 | 62649 | 95716 | 64236 | 95354 | 58 |
| 3 | 61016 | 96056 | 62676 | 95710 | 64262 | 95348 | 57 |
| 4 | 61045 | 96050 | 62703 | 95704 | 64288 | 95341 | 56 |
| 5 | 61073 | 96045 | 62730 | 95698 | 64313 | 95335 | 55 |
| 6 | 61101 | 96039 | 62757 | 95692 | 64339 | 95329 | 54 |
| 7 | 61129 | 96034 | 62784 | 95686 | 64365 | 95323 | 53 |
| 8 | 61158 | 96028 | 62811 | 95680 | 64391 | 95317 | 52 |
| 9 | 61186 | 96022 | 62838 | 95674 | 64417 | 95310 | 51 |
| 10 | 9.61214 | 9.96017 | 9.62865 | 9.95668 | 9.64442 | 9.95304 | 50 |
| 11 | 61242 | 96011 | 62892 | 95663 | 64468 | 95298 | 49 |
| 12 | 61270 | 96005 | 62918 | 95657 | 64494 | 95292 | 48 |
| 13 | 61298 | 96000 | 62945 | 95651 | 64519 | 95286 | 47 |
| 14 | 61326 | 95994 | 62972 | 95645 | 64545 | 95279 | 46 |
| 15 | 61354 | 95988 | 62999 | 95639 | 64571 | 95273 | 45 |
| 16 | 61382 | 95982 | 63026 | 95633 | 64596 | 95267 | 44 |
| 17 | 61411 | 95977 | 63052 | 95627 | 64622 | 95261 | 43 |
| 18 | 61438 | 95971 | 63079 | 95621 | 64647 | 95254 | 42 |
| 19 | 61466 | 95965 | 63106 | 95615 | 64673 | 95248 | 41 |
| 20 | 9.61494 | 9.95960 | 9.63133 | 9.95609 | 9.64698 | 9.95242 | 40 |
| 21 | 61522 | 95954 | 63159 | 95603 | 64724 | 95236 | 39 |
| 22 | 61550 | 95948 | 63186 | 95597 | 64749 | 95229 | 38 |
| 23 | 61578 | 95942 | 63213 | 95591 | 64775 | 95223 | 37 |
| 24 | 61606 | 95937 | 63239 | 95585 | 64800 | 95217 | 36 |
| 25 | 61634 | 95931 | 63266 | 95579 | 64826 | 95211 | 35 |
| 26 | 61662 | 95925 | 63292 | 95573 | 64851 | 95204 | 34 |
| 27 | 61689 | 95920 | 63319 | 95567 | 64877 | 95198 | 33 |
| 28 | 61717 | 95914 | 63345 | 95561 | 64902 | 95192 | 32 |
| 29 | 61745 | 95908 | 63372 | 95555 | 64927 | 95185 | 31 |
| 30 | 9.61773 | 9.95902 | 9.63398 | 9.95549 | 9.64953 | 9.95179 | 30 |
| 31 | 61800 | 95897 | 63425 | 95543 | 64978 | 95173 | 29 |
| 32 | 61828 | 95891 | 63451 | 95537 | 65003 | 95167 | 28 |
| 33 | 61856 | 95885 | 63478 | 95531 | 65029 | 95160 | 27 |
| 34 | 61883 | 95879 | 63504 | 95525 | 65054 | 95154 | 26 |
| 35 | 61911 | 95873 | 63531 | 95519 | 65079 | 95148 | 25 |
| 36 | 61939 | 95868 | 63557 | 95513 | 65104 | 95141 | 24 |
| 37 | 61966 | 95862 | 63583 | 95507 | 65130 | 95135 | 23 |
| 38 | 61994 | 95856 | 63610 | 95500 | 65155 | 95129 | 22 |
| 39 | 62021 | 95850 | 63636 | 95494 | 65180 | 95122 | 21 |
| 40 | 9.62049 | 9.95844 | 9.63662 | 9.95488 | 9.65205 | 9.95116 | 20 |
| 41 | 62076 | 95839 | 63689 | 95482 | 65230 | 95110 | 19 |
| 42 | 62104 | 95833 | 63715 | 95476 | 65255 | 95103 | 18 |
| 43 | 62131 | 95827 | 63741 | 95470 | 65281 | 95097 | 17 |
| 44 | 62159 | 95821 | 63767 | 95464 | 65306 | 95090 | 16 |
| 45 | 62186 | 95815 | 63794 | 95458 | 65331 | 95084 | 15 |
| 46 | 62214 | 95810 | 63820 | 95452 | 65356 | 95078 | 14 |
| 47 | 62241 | 95804 | 63846 | 95446 | 65381 | 95071 | 13 |
| 48 | 62268 | 95798 | 63872 | 95440 | 65406 | 95065 | 12 |
| 49 | 62296 | 95792 | 63898 | 95434 | 65431 | 95059 | 11 |
| 50 | 9.62323 | 9.95786 | 9.63924 | 9.95427 | 9.65456 | 9.95052 | 10 |
| 51 | 62350 | 95780 | 63950 | 95421 | 65481 | 95046 | 9 |
| 52 | 62377 | 95775 | 63976 | 95415 | 65506 | 95039 | 8 |
| 53 | 62405 | 95769 | 64002 | 95409 | 65531 | 95033 | 7 |
| 54 | 62432 | 95763 | 64028 | 95403 | 65565 | 95027 | 6 |
| 55 | 62459 | 95757 | 64054 | 95397 | 65580 | 95020 | 5 |
| 56 | 62486 | 95751 | 64080 | 95391 | 65605 | 95014 | 4 |
| 57 | 62513 | 95745 | 64106 | 95384 | 65630 | 95007 | 3 |
| 58 | 62541 | 95739 | 64132 | 95378 | 65655 | 95001 | 2 |
| 59 | 62568 | 95733 | 64158 | 95372 | 65680 | 94995 | 1 |
| 60 | 62595 | 95728 | 64184 | 95366 | 65705 | 94988 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 65° | | 64° | | 63° | | |

| ′ | 27° | | 28° | | 29° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.65705 | 9.94988 | 9.67161 | 9.94593 | 9.68557 | 9.94182 | 60 |
| 1 | 65729 | 94982 | 67185 | 94587 | 68580 | 94175 | 59 |
| 2 | 65754 | 94975 | 67208 | 94580 | 68603 | 94168 | 58 |
| 3 | 65779 | 94969 | 67232 | 94573 | 68625 | 94161 | 57 |
| 4 | 65804 | 94962 | 67256 | 94567 | 68648 | 94154 | 56 |
| 5 | 65828 | 94956 | 67280 | 94560 | 68671 | 94147 | 55 |
| 6 | 65853 | 94949 | 67303 | 94553 | 68694 | 94140 | 54 |
| 7 | 65878 | 94943 | 67327 | 94546 | 68716 | 94133 | 53 |
| 8 | 65902 | 94936 | 67350 | 94540 | 68739 | 94126 | 52 |
| 9 | 65927 | 94930 | 67374 | 94533 | 68762 | 94119 | 51 |
| 10 | 9.65952 | 9.94923 | 9.67398 | 9.94526 | 9.68784 | 9.94112 | 50 |
| 11 | 65976 | 94917 | 67421 | 94519 | 68807 | 94105 | 49 |
| 12 | 66001 | 94911 | 67445 | 94513 | 68829 | 94098 | 48 |
| 13 | 66025 | 94904 | 67468 | 94506 | 68852 | 94090 | 47 |
| 14 | 66050 | 94898 | 67492 | 94499 | 68875 | 94083 | 46 |
| 15 | 66075 | 94891 | 67515 | 94492 | 68897 | 94076 | 45 |
| 16 | 66099 | 94885 | 67539 | 94485 | 68920 | 94069 | 44 |
| 17 | 66124 | 94878 | 67562 | 94479 | 68942 | 94062 | 43 |
| 18 | 66148 | 94871 | 67586 | 94472 | 68965 | 94055 | 42 |
| 19 | 66173 | 94865 | 67609 | 94465 | 68987 | 94048 | 41 |
| 20 | 9.66197 | 9.94858 | 9.67633 | 9.94458 | 9.69010 | 9.94041 | 40 |
| 21 | 66221 | 94852 | 67656 | 94451 | 69032 | 94034 | 39 |
| 22 | 66246 | 94845 | 67680 | 94445 | 69055 | 94027 | 38 |
| 23 | 66270 | 94839 | 67703 | 94438 | 69077 | 94020 | 37 |
| 24 | 66295 | 94832 | 67726 | 94431 | 69100 | 94012 | 36 |
| 25 | 66319 | 94826 | 67750 | 94424 | 69122 | 94005 | 35 |
| 26 | 66343 | 94819 | 67773 | 94417 | 69144 | 93998 | 34 |
| 27 | 66368 | 94813 | 67796 | 94410 | 69167 | 93991 | 33 |
| 28 | 66392 | 94806 | 67820 | 94404 | 69189 | 93984 | 32 |
| 29 | 66416 | 94799 | 67843 | 94397 | 69212 | 93977 | 31 |
| 30 | 9.66441 | 9.94793 | 9.67866 | 9.94390 | 9.69234 | 9.93970 | 30 |
| 31 | 66465 | 94786 | 67890 | 94383 | 69256 | 93963 | 29 |
| 32 | 66489 | 94780 | 67913 | 94376 | 69279 | 93955 | 28 |
| 33 | 66513 | 94773 | 67936 | 94369 | 69301 | 93948 | 27 |
| 34 | 66537 | 94767 | 67959 | 94362 | 69323 | 93941 | 26 |
| 35 | 66562 | 94760 | 67982 | 94355 | 69345 | 93934 | 25 |
| 36 | 66586 | 94753 | 68006 | 94349 | 69368 | 93927 | 24 |
| 37 | 66610 | 94747 | 68029 | 94342 | 69390 | 93920 | 23 |
| 38 | 66634 | 94740 | 68052 | 94335 | 69412 | 93912 | 22 |
| 39 | 66658 | 94734 | 68075 | 94328 | 69434 | 93905 | 21 |
| 40 | 9.66682 | 9.94727 | 9.68098 | 9.94321 | 9.69456 | 9.93898 | 20 |
| 41 | 66706 | 94720 | 68121 | 94314 | 69479 | 93891 | 19 |
| 42 | 66731 | 94714 | 68144 | 94307 | 69501 | 93884 | 18 |
| 43 | 66755 | 94707 | 68167 | 94300 | 69523 | 93876 | 17 |
| 44 | 66779 | 94700 | 68190 | 94293 | 69545 | 93869 | 16 |
| 45 | 66803 | 94694 | 68213 | 94286 | 69567 | 93862 | 15 |
| 46 | 66827 | 94687 | 68237 | 94279 | 69589 | 93855 | 14 |
| 47 | 66851 | 94680 | 68260 | 94273 | 69611 | 93847 | 13 |
| 48 | 66875 | 94674 | 68283 | 94266 | 69633 | 93840 | 12 |
| 49 | 66899 | 94667 | 68305 | 94259 | 69655 | 93833 | 11 |
| 50 | 9.66922 | 9.94660 | 9.68328 | 9.94252 | 9.69677 | 9.93826 | 10 |
| 51 | 66946 | 94654 | 68351 | 94245 | 69699 | 93819 | 9 |
| 52 | 66970 | 94647 | 68374 | 94238 | 69721 | 93811 | 8 |
| 53 | 66994 | 94640 | 68397 | 94231 | 69743 | 93804 | 7 |
| 54 | 67018 | 94634 | 68420 | 94224 | 69765 | 93797 | 6 |
| 55 | 67042 | 94627 | 68443 | 94217 | 69787 | 93789 | 5 |
| 56 | 67066 | 94620 | 68466 | 94210 | 69809 | 93782 | 4 |
| 57 | 67090 | 94614 | 68489 | 94203 | 69831 | 93775 | 3 |
| 58 | 67113 | 94607 | 68512 | 94196 | 69853 | 93768 | 2 |
| 59 | 67137 | 94600 | 68534 | 94189 | 69875 | 93760 | 1 |
| 60 | 67161 | 94593 | 68557 | 94182 | 69897 | 93753 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 62° | | 61° | | 60° | | |

| ′ | 30° |  | 31° |  | 32° |  | ′ |
|---|---|---|---|---|---|---|---|
|  | Sine | Cosine | Sine | Cosine | Sine | Cosine |  |
| 0 | 9.69897 | 9.93753 | 9.71184 | 9.93307 | 9.72421 | 9.92842 | 60 |
| 1 | 69919 | 93746 | 71205 | 93299 | 72441 | 92834 | 59 |
| 2 | 69941 | 93738 | 71226 | 93291 | 72461 | 92826 | 58 |
| 3 | 69963 | 93731 | 71247 | 93284 | 72482 | 92818 | 57 |
| 4 | 69984 | 93724 | 71268 | 93276 | 72502 | 92810 | 56 |
| 5 | 70006 | 93717 | 71289 | 93269 | 72522 | 92803 | 55 |
| 6 | 70028 | 93709 | 71310 | 93261 | 72542 | 92795 | 54 |
| 7 | 70050 | 93702 | 71331 | 93253 | 72562 | 92787 | 53 |
| 8 | 70072 | 93695 | 71352 | 93246 | 72582 | 92779 | 52 |
| 9 | 70093 | 93687 | 71373 | 93238 | 72602 | 92771 | 51 |
| 10 | 9.70115 | 9.93680 | 9.71393 | 9.93230 | 9.72622 | 9.92763 | 50 |
| 11 | 70137 | 93673 | 71414 | 93223 | 72643 | 92755 | 49 |
| 12 | 70159 | 93665 | 71435 | 93215 | 72663 | 92747 | 48 |
| 13 | 70180 | 93658 | 71456 | 93207 | 72683 | 92739 | 47 |
| 14 | 70202 | 93650 | 71477 | 93200 | 72703 | 92731 | 46 |
| 15 | 70224 | 93643 | 71498 | 93192 | 72723 | 92723 | 45 |
| 16 | 70245 | 93636 | 71519 | 93184 | 72743 | 92715 | 44 |
| 17 | 70267 | 93628 | 71539 | 93177 | 72763 | 92707 | 43 |
| 18 | 70288 | 93621 | 71560 | 93169 | 72783 | 92699 | 42 |
| 19 | 70310 | 93614 | 71581 | 93161 | 72803 | 92691 | 41 |
| 20 | 9.70332 | 9.93606 | 9.71602 | 9.93154 | 9.72823 | 9.92683 | 40 |
| 21 | 70353 | 93599 | 71622 | 93146 | 72843 | 92675 | 39 |
| 22 | 70375 | 93591 | 71643 | 93138 | 72863 | 92667 | 38 |
| 23 | 70396 | 93584 | 71664 | 93131 | 72883 | 92659 | 37 |
| 24 | 70418 | 93577 | 71685 | 93123 | 72902 | 92651 | 36 |
| 25 | 70439 | 93569 | 71705 | 93115 | 72922 | 92643 | 35 |
| 26 | 70461 | 93562 | 71726 | 93108 | 72942 | 92635 | 34 |
| 27 | 70482 | 93554 | 71747 | 93100 | 72962 | 92627 | 33 |
| 28 | 70504 | 93547 | 71767 | 93092 | 72982 | 92619 | 32 |
| 29 | 70525 | 93539 | 71788 | 93084 | 73002 | 92611 | 31 |
| 30 | 9.70547 | 9.93532 | 9.71809 | 9.93077 | 9.73022 | 9.92603 | 30 |
| 31 | 70568 | 93525 | 71829 | 93069 | 73041 | 92595 | 29 |
| 32 | 70590 | 93517 | 71850 | 93061 | 73061 | 92587 | 28 |
| 33 | 70611 | 93510 | 71870 | 93053 | 73081 | 92579 | 27 |
| 34 | 70633 | 93502 | 71891 | 93046 | 73101 | 92571 | 26 |
| 35 | 70654 | 93495 | 71911 | 93038 | 73121 | 92563 | 25 |
| 36 | 70675 | 93487 | 71932 | 93030 | 73140 | 92555 | 24 |
| 37 | 70697 | 93480 | 71952 | 93022 | 73160 | 92546 | 23 |
| 38 | 70718 | 93472 | 71973 | 93014 | 73180 | 92538 | 22 |
| 39 | 70739 | 93465 | 71994 | 93007 | 73200 | 92530 | 21 |
| 40 | 9.70761 | 9.93457 | 9.72014 | 9.92999 | 9.73219 | 9.92522 | 20 |
| 41 | 70782 | 93450 | 72034 | 92991 | 73239 | 92514 | 19 |
| 42 | 70803 | 93442 | 72055 | 92983 | 73259 | 92506 | 18 |
| 43 | 70824 | 93435 | 72075 | 92976 | 73278 | 92498 | 17 |
| 44 | 70846 | 93427 | 72096 | 92968 | 73298 | 92490 | 16 |
| 45 | 70867 | 93420 | 72116 | 92960 | 73318 | 92482 | 15 |
| 46 | 70888 | 93412 | 72137 | 92952 | 73337 | 92473 | 14 |
| 47 | 70909 | 93405 | 72157 | 92944 | 73357 | 92465 | 13 |
| 48 | 70931 | 93397 | 72177 | 92936 | 73377 | 92457 | 12 |
| 49 | 70952 | 93390 | 72198 | 92929 | 73396 | 92449 | 11 |
| 50 | 9.70973 | 9.93382 | 9.72218 | 9.92921 | 9.73416 | 9.92441 | 10 |
| 51 | 70994 | 93375 | 72238 | 92913 | 73435 | 92433 | 9 |
| 52 | 71015 | 93367 | 72259 | 92905 | 73455 | 92425 | 8 |
| 53 | 71036 | 93360 | 72279 | 92897 | 73474 | 92416 | 7 |
| 54 | 71058 | 93352 | 72299 | 92889 | 73494 | 92408 | 6 |
| 55 | 71079 | 93344 | 72320 | 92881 | 73513 | 92400 | 5 |
| 56 | 71100 | 93337 | 72340 | 92874 | 73533 | 92392 | 4 |
| 57 | 71121 | 93329 | 72360 | 92866 | 73552 | 92384 | 3 |
| 58 | 71142 | 93322 | 72381 | 92858 | 73572 | 92376 | 2 |
| 59 | 71163 | 93314 | 72401 | 92850 | 73591 | 92367 | 1 |
| 60 | 71184 | 93307 | 72421 | 92842 | 73611 | 92359 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
|  | 59° |  | 58° |  | 57° |  |  |

| ′ | 33° | | 34° | | 35° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.73611 | 9.92359 | 9.74756 | 9.91857 | 9.75859 | 9.91336 | 60 |
| 1 | 73630 | 92351 | 74775 | 91849 | 75877 | 91328 | 59 |
| 2 | 73650 | 92343 | 74794 | 91840 | 75895 | 91319 | 58 |
| 3 | 73669 | 92335 | 74812 | 91832 | 75913 | 91310 | 57 |
| 4 | 73689 | 92326 | 74831 | 91823 | 75931 | 91301 | 56 |
| 5 | 73708 | 92318 | 74850 | 91815 | 75949 | 91292 | 55 |
| 6 | 73727 | 92310 | 74868 | 91806 | 75967 | 91283 | 54 |
| 7 | 73747 | 92302 | 74887 | 91798 | 75985 | 91274 | 53 |
| 8 | 73766 | 92293 | 74906 | 91789 | 76003 | 91266 | 52 |
| 9 | 73785 | 92285 | 74924 | 91781 | 76021 | 91257 | 51 |
| 10 | 9.73805 | 9.92277 | 9.74943 | 9.91772 | 9.76039 | 9.91248 | 50 |
| 11 | 73824 | 92269 | 74961 | 91763 | 76057 | 91239 | 49 |
| 12 | 73843 | 92260 | 74980 | 91755 | 76075 | 91230 | 48 |
| 13 | 73863 | 92252 | 74999 | 91746 | 76093 | 91221 | 47 |
| 14 | 73882 | 92244 | 75017 | 91738 | 76111 | 91212 | 46 |
| 15 | 73901 | 92235 | 75036 | 91729 | 76129 | 91203 | 45 |
| 16 | 73921 | 92227 | 75054 | 91720 | 76146 | 91194 | 44 |
| 17 | 73940 | 92219 | 75073 | 91712 | 76164 | 91185 | 43 |
| 18 | 73959 | 92211 | 75091 | 91703 | 76182 | 91176 | 42 |
| 19 | 73978 | 92202 | 75110 | 91695 | 76200 | 91167 | 41 |
| 20 | 9.73997 | 9.92194 | 9.75128 | 9.91686 | 9.76218 | 9.91158 | 40 |
| 21 | 74017 | 92186 | 75147 | 91677 | 76236 | 91149 | 39 |
| 22 | 74036 | 92177 | 75165 | 91669 | 76253 | 91141 | 38 |
| 23 | 74055 | 92169 | 75184 | 91660 | 76271 | 91132 | 37 |
| 24 | 74074 | 92161 | 75202 | 91651 | 76289 | 91123 | 36 |
| 25 | 74093 | 92152 | 75221 | 91643 | 76307 | 91114 | 35 |
| 26 | 74113 | 92144 | 75239 | 91634 | 76324 | 91105 | 34 |
| 27 | 74132 | 92136 | 75258 | 91625 | 76342 | 91096 | 33 |
| 28 | 74151 | 92127 | 75276 | 91617 | 76360 | 91087 | 32 |
| 29 | 74170 | 92119 | 75294 | 91608 | 76378 | 91078 | 31 |
| 30 | 9.74189 | 9.92111 | 9.75313 | 9.91599 | 9.76395 | 9.91069 | 30 |
| 31 | 74208 | 92102 | 75331 | 91591 | 76413 | 91060 | 29 |
| 32 | 74227 | 92094 | 75350 | 91582 | 76431 | 91051 | 28 |
| 33 | 74246 | 92086 | 75368 | 91573 | 76448 | 91042 | 27 |
| 34 | 74265 | 92077 | 75386 | 91565 | 76466 | 91033 | 26 |
| 35 | 74284 | 92069 | 75405 | 91556 | 76484 | 91023 | 25 |
| 36 | 74303 | 92060 | 75423 | 91547 | 76501 | 91014 | 24 |
| 37 | 74322 | 92052 | 75441 | 91538 | 76519 | 91005 | 23 |
| 38 | 74341 | 92044 | 75459 | 91530 | 76537 | 90996 | 22 |
| 39 | 74360 | 92035 | 75478 | 91521 | 76554 | 90987 | 21 |
| 40 | 9.74379 | 9.92027 | 9.75496 | 9.91512 | 9.76572 | 9.90978 | 20 |
| 41 | 74398 | 92018 | 75514 | 91504 | 76590 | 90969 | 19 |
| 42 | 74417 | 92010 | 75533 | 91495 | 76607 | 90960 | 18 |
| 43 | 74436 | 92002 | 75551 | 91486 | 76625 | 90951 | 17 |
| 44 | 74455 | 91993 | 75569 | 91477 | 76642 | 90942 | 16 |
| 45 | 74474 | 91985 | 75587 | 91469 | 76660 | 90933 | 15 |
| 46 | 74493 | 91976 | 75605 | 91460 | 76677 | 90924 | 14 |
| 47 | 74512 | 91968 | 75624 | 91451 | 76695 | 90915 | 13 |
| 48 | 74531 | 91959 | 75642 | 91442 | 76712 | 90906 | 12 |
| 49 | 74549 | 91951 | 75660 | 91433 | 76730 | 90896 | 11 |
| 50 | 9.74568 | 9.91942 | 9.75678 | 9.91425 | 9.76747 | 9.90887 | 10 |
| 51 | 74587 | 91934 | 75696 | 91416 | 76765 | 90878 | 9 |
| 52 | 74606 | 91925 | 75714 | 91407 | 76782 | 90869 | 8 |
| 53 | 74625 | 91917 | 75733 | 91398 | 76800 | 90860 | 7 |
| 54 | 74644 | 91908 | 75751 | 91389 | 76817 | 90851 | 6 |
| 55 | 74662 | 91900 | 75769 | 91381 | 76835 | 90842 | 5 |
| 56 | 74681 | 91891 | 75787 | 91372 | 76852 | 90832 | 4 |
| 57 | 74700 | 91883 | 75805 | 91363 | 76870 | 90823 | 3 |
| 58 | 74719 | 91874 | 75823 | 91354 | 76887 | 90814 | 2 |
| 59 | 74737 | 91866 | 75841 | 91345 | 76904 | 90805 | 1 |
| 60 | 74756 | 91857 | 75859 | 91336 | 76922 | 90796 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 56° | | 55° | | 54° | | |

## TABLE VII.—LOGARITHMIC SINES AND COSINES.

| ′ | 36° | | 37° | | 38° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.76922 | 9.90796 | 9.77946 | 9.90235 | 9.78934 | 9.89653 | 60 |
| 1 | 76939 | 90787 | 77963 | 90225 | 78950 | 89643 | 59 |
| 2 | 76957 | 90777 | 77980 | 90216 | 78967 | 89633 | 58 |
| 3 | 76974 | 90768 | 77997 | 90206 | 78983 | 89624 | 57 |
| 4 | 76991 | 90759 | 78013 | 90197 | 78999 | 89614 | 56 |
| 5 | 77009 | 90750 | 78030 | 90187 | 79015 | 89604 | 55 |
| 6 | 77026 | 90741 | 78047 | 90178 | 79031 | 89594 | 54 |
| 7 | 77043 | 90731 | 78063 | 90168 | 79047 | 89584 | 53 |
| 8 | 77061 | 90722 | 78080 | 90159 | 79063 | 89574 | 52 |
| 9 | 77078 | 90713 | 78097 | 90149 | 79079 | 89564 | 51 |
| 10 | 9.77095 | 9.90704 | 9.78113 | 9.90139 | 9.79095 | 9.89554 | 50 |
| 11 | 77112 | 90694 | 78130 | 90130 | 79111 | 89544 | 49 |
| 12 | 77130 | 90685 | 78147 | 90120 | 79128 | 89534 | 48 |
| 13 | 77147 | 90676 | 78163 | 90111 | 79144 | 89524 | 47 |
| 14 | 77164 | 90667 | 78180 | 90101 | 79160 | 89514 | 46 |
| 15 | 77181 | 90657 | 78197 | 90091 | 79176 | 89504 | 45 |
| 16 | 77199 | 90648 | 78213 | 90082 | 79192 | 89495 | 44 |
| 17 | 77216 | 90639 | 78230 | 90072 | 79208 | 89485 | 43 |
| 18 | 77233 | 90630 | 78246 | 90063 | 79224 | 89475 | 42 |
| 19 | 77250 | 90620 | 78263 | 90053 | 79240 | 89465 | 41 |
| 20 | 9.77268 | 9.90611 | 9.78280 | 9.90043 | 9.79256 | 9.89455 | 40 |
| 21 | 77285 | 90602 | 78296 | 90034 | 79272 | 89445 | 39 |
| 22 | 77302 | 90592 | 78313 | 90024 | 79288 | 89435 | 38 |
| 23 | 77319 | 90583 | 78329 | 90014 | 79304 | 89425 | 37 |
| 24 | 77336 | 90574 | 78346 | 90005 | 79319 | 89415 | 36 |
| 25 | 77353 | 90565 | 78362 | 89995 | 79335 | 89405 | 35 |
| 26 | 77370 | 90555 | 78379 | 89985 | 79351 | 89395 | 34 |
| 27 | 77387 | 90546 | 78395 | 89976 | 79367 | 89385 | 33 |
| 28 | 77405 | 90537 | 78412 | 89966 | 79383 | 89375 | 32 |
| 29 | 77422 | 90527 | 78428 | 89956 | 79399 | 89364 | 31 |
| 30 | 9.77439 | 9.90518 | 9.78445 | 9.89947 | 9.79415 | 9.89354 | 30 |
| 31 | 77456 | 90509 | 78461 | 89937 | 79431 | 89344 | 29 |
| 32 | 77473 | 90499 | 78478 | 89927 | 79447 | 89334 | 28 |
| 33 | 77490 | 90490 | 78494 | 89918 | 79463 | 89324 | 27 |
| 34 | 77507 | 90480 | 78510 | 89908 | 79478 | 89314 | 26 |
| 35 | 77524 | 90471 | 78527 | 89898 | 79494 | 89304 | 25 |
| 36 | 77541 | 90462 | 78543 | 89888 | 79510 | 89294 | 24 |
| 37 | 77558 | 90452 | 78560 | 89879 | 79526 | 89284 | 23 |
| 38 | 77575 | 90443 | 78576 | 89869 | 79542 | 89274 | 22 |
| 39 | 77592 | 90434 | 78592 | 89859 | 79558 | 89264 | 21 |
| 40 | 9.77609 | 9.90424 | 9.78609 | 9.89849 | 9.79573 | 9.89254 | 20 |
| 41 | 77626 | 90415 | 78625 | 89840 | 79589 | 89244 | 19 |
| 42 | 77643 | 90405 | 78642 | 89830 | 79605 | 89233 | 18 |
| 43 | 77660 | 90396 | 78658 | 89820 | 78621 | 89223 | 17 |
| 44 | 77677 | 90386 | 78674 | 89810 | 79636 | 89213 | 16 |
| 45 | 77694 | 90377 | 78691 | 89801 | 79652 | 89203 | 15 |
| 46 | 77711 | 90368 | 78707 | 89791 | 79668 | 89193 | 14 |
| 47 | 77728 | 90358 | 78723 | 89781 | 79684 | 89183 | 13 |
| 48 | 77744 | 90349 | 78739 | 89771 | 79699 | 89173 | 12 |
| 49 | 77761 | 90339 | 78756 | 89761 | 79715 | 89162 | 11 |
| 50 | 9.77778 | 9.90330 | 9.78772 | 9.89752 | 9.79731 | 9.89152 | 10 |
| 51 | 77795 | 90320 | 78788 | 89742 | 79746 | 89142 | 9 |
| 52 | 77812 | 90311 | 78805 | 89732 | 79762 | 89132 | 8 |
| 53 | 77829 | 90301 | 78821 | 89722 | 79778 | 89122 | 7 |
| 54 | 77846 | 90292 | 78837 | 89712 | 79793 | 89112 | 6 |
| 55 | 77862 | 90282 | 78853 | 89702 | 79809 | 89101 | 5 |
| 56 | 77879 | 90273 | 78869 | 89693 | 79825 | 89091 | 4 |
| 57 | 77896 | 90263 | 78886 | 89683 | 79840 | 89081 | 3 |
| 58 | 77913 | 90254 | 78902 | 89673 | 79856 | 89071 | 2 |
| 59 | 77930 | 90244 | 78918 | 89663 | 79872 | 89060 | 1 |
| 60 | 77946 | 90235 | 78934 | 89653 | 79887 | 89050 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 53° | | 52° | | 51° | | |

| ′ | 39° | | 40° | | 41° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.79887 | 9.89050 | 9.80807 | 9.88425 | 9.81694 | 9.87778 | 60 |
| 1 | 79903 | 89040 | 80822 | 88415 | 81709 | 87767 | 59 |
| 2 | 79918 | 89030 | 80837 | 88404 | 81723 | 87756 | 58 |
| 3 | 79934 | 89020 | 80852 | 88394 | 81738 | 87745 | 57 |
| 4 | 79950 | 89009 | 80867 | 88383 | 81752 | 87734 | 56 |
| 5 | 79965 | 88999 | 80882 | 88372 | 81767 | 87723 | 55 |
| 6 | 79981 | 88989 | 80897 | 88362 | 81781 | 87712 | 54 |
| 7 | 79996 | 88978 | 80912 | 88351 | 81796 | 87701 | 53 |
| 8 | 80012 | 88968 | 80927 | 88340 | 81810 | 87690 | 52 |
| 9 | 80027 | 88958 | 80942 | 88330 | 81825 | 87679 | 51 |
| 10 | 9.80043 | 9.88948 | 9.80957 | 9.88319 | 9.81839 | 9.87668 | 50 |
| 11 | 80058 | 88937 | 80972 | 88308 | 81854 | 87657 | 49 |
| 12 | 80074 | 88927 | 80987 | 88298 | 81868 | 87646 | 48 |
| 13 | 80089 | 88917 | 81002 | 88287 | 81882 | 87635 | 47 |
| 14 | 80105 | 88906 | 81017 | 88276 | 81897 | 87624 | 46 |
| 15 | 80120 | 88896 | 81032 | 88266 | 81911 | 87613 | 45 |
| 16 | 80136 | 88886 | 81047 | 88255 | 81926 | 87601 | 44 |
| 17 | 80151 | 88875 | 81061 | 88244 | 81940 | 87590 | 43 |
| 18 | 80166 | 88865 | 81076 | 88234 | 81955 | 87579 | 42 |
| 19 | 80182 | 88855 | 81091 | 88223 | 81969 | 87568 | 41 |
| 20 | 9.80197 | 9.88844 | 9.81106 | 9.88212 | 9.81983 | 9.87557 | 40 |
| 21 | 80213 | 88834 | 81121 | 88201 | 81998 | 87546 | 39 |
| 22 | 80228 | 88824 | 81136 | 88191 | 82012 | 87535 | 38 |
| 23 | 80244 | 88813 | 81151 | 88180 | 82026 | 87524 | 37 |
| 24 | 80259 | 88803 | 81166 | 88169 | 82041 | 87513 | 36 |
| 25 | 80274 | 88793 | 81180 | 88158 | 82055 | 87501 | 35 |
| 26 | 80290 | 88782 | 81195 | 88148 | 82069 | 87490 | 34 |
| 27 | 80305 | 88772 | 81210 | 88137 | 82084 | 87479 | 33 |
| 28 | 80320 | 88761 | 81225 | 88126 | 82098 | 87468 | 32 |
| 29 | 80336 | 88751 | 81240 | 88115 | 82112 | 87457 | 31 |
| 30 | 9.80351 | 9.88741 | 9.81254 | 9.88105 | 9.82126 | 9.87446 | 30 |
| 31 | 80366 | 88730 | 81269 | 88094 | 82141 | 87434 | 29 |
| 32 | 80382 | 88720 | 81284 | 88083 | 82155 | 87423 | 28 |
| 33 | 80397 | 88709 | 81299 | 88072 | 82169 | 87412 | 27 |
| 34 | 80412 | 88699 | 81314 | 88061 | 82184 | 87401 | 26 |
| 35 | 80428 | 88688 | 81328 | 88051 | 82198 | 87390 | 25 |
| 36 | 80443 | 88678 | 81343 | 88040 | 82212 | 87378 | 24 |
| 37 | 80458 | 88668 | 81358 | 88029 | 82226 | 87367 | 23 |
| 38 | 80473 | 88657 | 81372 | 88018 | 82240 | 87356 | 22 |
| 39 | 80489 | 88647 | 81387 | 88007 | 82255 | 87345 | 21 |
| 40 | 9.80504 | 9.88636 | 9.81402 | 9.87996 | 9.82269 | 9.87334 | 20 |
| 41 | 80519 | 88626 | 81417 | 87985 | 82283 | 87322 | 19 |
| 42 | 80534 | 88615 | 81431 | 87975 | 82297 | 87311 | 18 |
| 43 | 80550 | 88605 | 81446 | 87964 | 82311 | 87300 | 17 |
| 44 | 80565 | 88594 | 81461 | 87953 | 82326 | 87288 | 16 |
| 45 | 80580 | 88584 | 81475 | 87942 | 82340 | 87277 | 15 |
| 46 | 80595 | 88573 | 81490 | 87931 | 82354 | 87266 | 14 |
| 47 | 80610 | 88563 | 81505 | 87920 | 82368 | 87255 | 13 |
| 48 | 80625 | 88552 | 81519 | 87909 | 82382 | 87243 | 12 |
| 49 | 80641 | 88542 | 81534 | 87898 | 82396 | 87232 | 11 |
| 50 | 9.80656 | 9.88531 | 9.81549 | 9.87887 | 9.82410 | 9.87221 | 10 |
| 51 | 80671 | 88521 | 81563 | 87877 | 82424 | 87209 | 9 |
| 52 | 80686 | 88510 | 81578 | 87866 | 82439 | 87198 | 8 |
| 53 | 80701 | 88499 | 81592 | 87855 | 82453 | 87187 | 7 |
| 54 | 80716 | 88489 | 81607 | 87844 | 82467 | 87175 | 6 |
| 55 | 80731 | 88478 | 81622 | 87833 | 82481 | 87164 | 5 |
| 56 | 80746 | 88468 | 81636 | 87822 | 82495 | 87153 | 4 |
| 57 | 80762 | 88457 | 81651 | 87811 | 82509 | 87141 | 3 |
| 58 | 80777 | 88447 | 81665 | 87800 | 82523 | 87130 | 2 |
| 59 | 80792 | 88436 | 81680 | 87789 | 82537 | 87119 | 1 |
| 60 | 80807 | 88425 | 81694 | 87778 | 82551 | 87107 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 50° | | 49° | | 48° | | |

| ′ | 42° | | 43° | | 44° | | ′ |
|---|---|---|---|---|---|---|---|
| | Sine | Cosine | Sine | Cosine | Sine | Cosine | |
| 0 | 9.82551 | 9.87107 | 9.83378 | 9.86413 | 9.84177 | 9.85693 | 60 |
| 1 | 82565 | 87096 | 83392 | 86401 | 84190 | 85681 | 59 |
| 2 | 82579 | 87085 | 83405 | 86389 | 84203 | 85669 | 58 |
| 3 | 82593 | 87073 | 83419 | 86377 | 84216 | 85657 | 57 |
| 4 | 82607 | 87062 | 83432 | 86366 | 84229 | 85645 | 56 |
| 5 | 82621 | 87050 | 83446 | 86354 | 84242 | 85632 | 55 |
| 6 | 82635 | 87039 | 83459 | 86342 | 84255 | 85620 | 54 |
| 7 | 82649 | 87028 | 83478 | 86330 | 84269 | 85608 | 53 |
| 8 | 82663 | 87016 | 83486 | 86318 | 84282 | 85596 | 52 |
| 9 | 82677 | 87005 | 83500 | 86306 | 84295 | 85583 | 51 |
| 10 | 9.82691 | 9.86993 | 9.83513 | 9.86295 | 9.84308 | 9.85571 | 50 |
| 11 | 82705 | 86982 | 83527 | 86283 | 84321 | 85559 | 49 |
| 12 | 82719 | 86970 | 83540 | 86271 | 84334 | 85547 | 48 |
| 13 | 82733 | 86959 | 83554 | 86259 | 84347 | 85534 | 47 |
| 14 | 82747 | 86947 | 83567 | 86247 | 84360 | 85522 | 46 |
| 15 | 82761 | 86936 | 83581 | 86235 | 84373 | 85510 | 45 |
| 16 | 82775 | 86924 | 83594 | 86223 | 84385 | 85497 | 44 |
| 17 | 82788 | 86913 | 83608 | 86211 | 84398 | 85485 | 43 |
| 18 | 82802 | 86902 | 83621 | 86200 | 84411 | 85473 | 42 |
| 19 | 82816 | 86890 | 83634 | 86188 | 84424 | 85460 | 41 |
| 20 | 9.82830 | 9.86879 | 9.83648 | 9.86176 | 9.84437 | 9.85448 | 40 |
| 21 | 82844 | 86867 | 83661 | 86164 | 84450 | 85436 | 39 |
| 22 | 82858 | 86855 | 83674 | 86152 | 84463 | 85423 | 38 |
| 23 | 82872 | 86844 | 83688 | 86140 | 84476 | 85411 | 37 |
| 24 | 82885 | 86832 | 83701 | 86128 | 84489 | 85399 | 36 |
| 25 | 82899 | 86821 | 83715 | 86116 | 84502 | 85386 | 35 |
| 26 | 82913 | 86809 | 83728 | 86104 | 84515 | 85374 | 34 |
| 27 | 82927 | 86798 | 83741 | 86092 | 84528 | 85361 | 33 |
| 28 | 82941 | 86786 | 83755 | 86080 | 84540 | 85349 | 32 |
| 29 | 82955 | 86775 | 83768 | 86068 | 84553 | 85337 | 31 |
| 30 | 9.82968 | 9.86763 | 9.83781 | 9.86056 | 9.84566 | 9.85324 | 30 |
| 31 | 82982 | 86752 | 83795 | 86044 | 84579 | 85312 | 29 |
| 32 | 82996 | 86740 | 83808 | 86032 | 84592 | 85299 | 28 |
| 33 | 83010 | 86728 | 83821 | 86020 | 84605 | 85287 | 27 |
| 34 | 83023 | 86717 | 83834 | 86008 | 84618 | 85274 | 26 |
| 35 | 83037 | 86705 | 83848 | 85996 | 84630 | 85262 | 25 |
| 36 | 83051 | 86694 | 83861 | 85984 | 84643 | 85250 | 24 |
| 37 | 83065 | 86682 | 83874 | 85972 | 84656 | 85237 | 23 |
| 38 | 83078 | 86670 | 83887 | 85960 | 84669 | 85225 | 22 |
| 39 | 83092 | 86659 | 83901 | 85948 | 84682 | 85212 | 21 |
| 40 | 9.83106 | 9.86647 | 9.83914 | 9.85936 | 9.84694 | 9.85200 | 20 |
| 41 | 83120 | 86635 | 83927 | 85924 | 84707 | 85187 | 19 |
| 42 | 83133 | 86624 | 83940 | 85912 | 84720 | 85175 | 18 |
| 43 | 83147 | 86612 | 83954 | 85900 | 84733 | 85162 | 17 |
| 44 | 83161 | 86600 | 83967 | 85888 | 84745 | 85150 | 16 |
| 45 | 83174 | 86589 | 83980 | 85876 | 84758 | 85137 | 15 |
| 46 | 83188 | 86577 | 83993 | 85864 | 84771 | 85125 | 14 |
| 47 | 83202 | 86565 | 84006 | 85851 | 84784 | 85112 | 13 |
| 48 | 83215 | 86554 | 84020 | 85839 | 84796 | 85100 | 12 |
| 49 | 83229 | 86542 | 84033 | 85827 | 84809 | 85087 | 11 |
| 50 | 9.83242 | 9.86530 | 9.84046 | 9.85815 | 9.84822 | 9.85074 | 10 |
| 51 | 83256 | 86518 | 84059 | 85803 | 84835 | 85062 | 9 |
| 52 | 83270 | 86507 | 84072 | 85791 | 84847 | 85049 | 8 |
| 53 | 83283 | 86495 | 84085 | 85779 | 84860 | 85037 | 7 |
| 54 | 83297 | 86483 | 84098 | 85766 | 84873 | 85024 | 6 |
| 55 | 83310 | 86472 | 84112 | 85754 | 84885 | 85012 | 5 |
| 56 | 83324 | 86460 | 84125 | 85742 | 84898 | 84999 | 4 |
| 57 | 83338 | 86448 | 84138 | 85730 | 84911 | 84986 | 3 |
| 58 | 83351 | 86436 | 84151 | 85718 | 84923 | 84974 | 2 |
| 59 | 83365 | 86425 | 84164 | 85706 | 84936 | 84961 | 1 |
| 60 | 83378 | 86413 | 84177 | 85693 | 84949 | 84949 | 0 |
| ′ | Cosine | Sine | Cosine | Sine | Cosine | Sine | ′ |
| | 47° | | 46° | | 45° | | |

| ′ | 0° | | 1° | | 2° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | — ∞ | ∞ | 8.24192 | 11.75808 | 8.54308 | 11.45692 | 60 |
| 1 | 6.46373 | 13.53627 | 24910 | 75090 | 54669 | 45331 | 59 |
| 2 | 76476 | 23524 | 25616 | 74384 | 55027 | 44973 | 58 |
| 3 | 94085 | 05915 | 26312 | 73688 | 55382 | 44618 | 57 |
| 4 | 7.06579 | 12.93421 | 26996 | 73004 | 55734 | 44266 | 56 |
| 5 | 16270 | 83730 | 27669 | 72331 | 56083 | 43917 | 55 |
| 6 | 24188 | 75812 | 28332 | 71668 | 56429 | 43571 | 54 |
| 7 | 30882 | 69118 | 28986 | 71014 | 56773 | 43227 | 53 |
| 8 | 36682 | 63318 | 29629 | 70371 | 57114 | 42886 | 52 |
| 9 | 41797 | 58203 | 30263 | 69737 | 57452 | 42548 | 51 |
| 10 | 7.46373 | 12.53627 | 8.30888 | 11.69112 | 8.57788 | 11.42212 | 50 |
| 11 | 50512 | 49488 | 31505 | 68495 | 58121 | 41879 | 49 |
| 12 | 54291 | 45709 | 32112 | 67888 | 58451 | 41549 | 48 |
| 13 | 57767 | 42233 | 32711 | 67289 | 58779 | 41221 | 47 |
| 14 | 60986 | 39014 | 33302 | 66698 | 59105 | 40895 | 46 |
| 15 | 63982 | 36018 | 33886 | 66114 | 59428 | 40572 | 45 |
| 16 | 66785 | 33215 | 34461 | 65539 | 59749 | 40251 | 44 |
| 17 | 69418 | 30582 | 35029 | 64971 | 60068 | 39932 | 43 |
| 18 | 71900 | 28100 | 35590 | 64410 | 60384 | 39616 | 42 |
| 19 | 74248 | 25752 | 36143 | 63857 | 60698 | 39302 | 41 |
| 20 | 7 76476 | 12.23524 | 8.36689 | 11.63311 | 8.61009 | 11.38991 | 40 |
| 21 | 78595 | 21405 | 37229 | 62771 | 61319 | 38681 | 39 |
| 22 | 80615 | 19385 | 37762 | 62238 | 61626 | 38374 | 38 |
| 23 | 82546 | 17454 | 38289 | 61711 | 61931 | 38069 | 37 |
| 24 | 84394 | 15606 | 38809 | 61191 | 62234 | 37766 | 36 |
| 25 | 86167 | 13833 | 39323 | 60677 | 62535 | 37465 | 35 |
| 26 | 87871 | 12129 | 39832 | 60168 | 62834 | 37166 | 34 |
| 27 | 89510 | 10490 | 40334 | 59666 | 63131 | 36869 | 33 |
| 28 | 91089 | 08911 | 40830 | 59170 | 63426 | 36574 | 32 |
| 29 | 92613 | 07387 | 41321 | 58679 | 63718 | 36282 | 31 |
| 30 | 7.94086 | 12.05914 | 8.41807 | 11.58193 | 8.64009 | 11.35991 | 30 |
| 31 | 95510 | 04490 | 42287 | 57713 | 64298 | 35702 | 29 |
| 32 | 96889 | 03111 | 42762 | 57238 | 64585 | 35415 | 28 |
| 33 | 98225 | 01775 | 43232 | 56768 | 64870 | 35130 | 27 |
| 34 | 99522 | 00478 | 43696 | 56304 | 65154 | 34846 | 26 |
| 35 | 8.00781 | 11.99219 | 44156 | 55844 | 65435 | 34565 | 25 |
| 36 | 02004 | 97996 | 44611 | 55389 | 65715 | 34285 | 24 |
| 37 | 03194 | 96806 | 45061 | 54939 | 65993 | 34007 | 23 |
| 38 | 04353 | 95647 | 45507 | 54493 | 66269 | 33731 | 22 |
| 39 | 05481 | 94519 | 45948 | 54052 | 66543 | 33457 | 21 |
| 40 | 8.06581 | 11.93419 | 8.46385 | 11.53615 | 8.66816 | 11.33184 | 20 |
| 41 | 07653 | 92347 | 46817 | 53183 | 67087 | 32913 | 19 |
| 42 | 08700 | 91300 | 47245 | 52755 | 67356 | 32644 | 18 |
| 43 | 09722 | 90278 | 47669 | 52331 | 67624 | 32376 | 17 |
| 44 | 10720 | 89280 | 48089 | 51911 | 67890 | 32110 | 16 |
| 45 | 11696 | 88304 | 48505 | 51495 | 68154 | 31846 | 15 |
| 46 | 12651 | 87349 | 48917 | 51083 | 68417 | 31583 | 14 |
| 47 | 13585 | 86415 | 49325 | 50675 | 68678 | 31322 | 13 |
| 48 | 14500 | 85500 | 49729 | 50271 | 68938 | 31062 | 12 |
| 49 | 15395 | 84605 | 50130 | 49870 | 69196 | 30804 | 11 |
| 50 | 8.16273 | 11.83727 | 8.50527 | 11.49473 | 8.69453 | 11.30547 | 10 |
| 51 | 17133 | 82867 | 50920 | 49080 | 69708 | 30292 | 9 |
| 52 | 17976 | 82024 | 51310 | 48690 | 69962 | 30038 | 8 |
| 53 | 18804 | 81196 | 51696 | 48304 | 70214 | 29786 | 7 |
| 54 | 19616 | 80384 | 52079 | 47921 | 70465 | 29535 | 6 |
| 55 | 20413 | 79587 | 52459 | 47541 | 70714 | 29286 | 5 |
| 56 | 21195 | 78805 | 52835 | 47165 | 70962 | 29038 | 4 |
| 57 | 21964 | 78036 | 53208 | 46792 | 71208 | 28792 | 3 |
| 58 | 22720 | 77280 | 53578 | 46422 | 71453 | 28547 | 2 |
| 59 | 23462 | 76538 | 53945 | 46055 | 71697 | 28303 | 1 |
| 60 | 24192 | 75808 | 54308 | 45692 | 71940 | 28060 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 89° | | 88° | | 87° | | |

| ′ | 3° | | 4° | | 5° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 8.71940 | 11.28060 | 8.84464 | 11.15536 | 8.94195 | 11.05805 | 60 |
| 1 | 72181 | 27819 | 84646 | 15354 | 94340 | 05660 | 59 |
| 2 | 72420 | 27580 | 84826 | 15174 | 94485 | 05515 | 58 |
| 3 | 72659 | 27341 | 85006 | 14994 | 94630 | 05370 | 57 |
| 4 | 72896 | 27104 | 85185 | 14815 | 94773 | 05227 | 56 |
| 5 | 73132 | 26868 | 85363 | 14637 | 94917 | 05083 | 55 |
| 6 | 73366 | 26634 | 85540 | 14460 | 95060 | 04940 | 54 |
| 7 | 73600 | 26400 | 85717 | 14283 | 95202 | 04798 | 53 |
| 8 | 73832 | 26168 | 85893 | 14107 | 95344 | 04656 | 52 |
| 9 | 74063 | 25937 | 86069 | 13931 | 95486 | 04514 | 51 |
| 10 | 8.74292 | 11.25708 | 8.86243 | 11.13757 | 8.95627 | 11.04373 | 50 |
| 11 | 74521 | 25479 | 86417 | 13583 | 95767 | 04233 | 49 |
| 12 | 74748 | 25252 | 86591 | 13409 | 95908 | 04092 | 48 |
| 13 | 74974 | 25026 | 86763 | 13237 | 96047 | 03953 | 47 |
| 14 | 75199 | 24801 | 86935 | 13065 | 96187 | 03813 | 46 |
| 15 | 75423 | 24577 | 87106 | 12894 | 96325 | 03675 | 45 |
| 16 | 75645 | 24355 | 87277 | 12723 | 96464 | 03536 | 44 |
| 17 | 75867 | 24133 | 87447 | 12553 | 96602 | 03398 | 43 |
| 18 | 76087 | 23913 | 87616 | 12384 | 96739 | 03261 | 42 |
| 19 | 76306 | 23694 | 87785 | 12215 | 96877 | 03123 | 41 |
| 20 | 8.76525 | 11.23475 | 8.87953 | 11.12047 | 8.97013 | 11.02987 | 40 |
| 21 | 76742 | 23258 | 88120 | 11880 | 97150 | 02850 | 39 |
| 22 | 76958 | 23042 | 88287 | 11713 | 97285 | 02715 | 38 |
| 23 | 77173 | 22827 | 88453 | 11547 | 97421 | 02579 | 37 |
| 24 | 77387 | 22613 | 88618 | 11382 | 97556 | 02444 | 36 |
| 25 | 77600 | 22400 | 88783 | 11217 | 97691 | 02309 | 35 |
| 26 | 77811 | 22189 | 88948 | 11052 | 97825 | 02175 | 34 |
| 27 | 78022 | 21978 | 89111 | 10889 | 97959 | 02041 | 33 |
| 28 | 78232 | 21768 | 89274 | 10726 | 98092 | 01908 | 32 |
| 29 | 78441 | 21559 | 89437 | 10563 | 98225 | 01775 | 31 |
| 30 | 8.78649 | 11.21351 | 8.89598 | 11.10402 | 8.98358 | 11.01642 | 30 |
| 31 | 78855 | 21145 | 89760 | 10240 | 98490 | 01510 | 29 |
| 32 | 79061 | 20939 | 89920 | 10080 | 98622 | 01378 | 28 |
| 33 | 79266 | 20734 | 90080 | 09920 | 98753 | 01247 | 27 |
| 34 | 79470 | 20530 | 90240 | 09760 | 98884 | 01116 | 26 |
| 35 | 79673 | 20327 | 90399 | 09601 | 99015 | 00985 | 25 |
| 36 | 79875 | 20125 | 90557 | 09443 | 99145 | 00855 | 24 |
| 37 | 80076 | 19924 | 90715 | 09285 | 99275 | 00725 | 23 |
| 38 | 80277 | 19723 | 90872 | 09128 | 99405 | 00595 | 22 |
| 39 | 80476 | 19524 | 91029 | 08971 | 99534 | 00466 | 21 |
| 40 | 8.80674 | 11.19326 | 8.91185 | 11.08815 | 8.99662 | 11.00338 | 20 |
| 41 | 80872 | 19128 | 91340 | 08660 | 99791 | 00209 | 19 |
| 42 | 81068 | 18932 | 91495 | 08505 | 99919 | 00081 | 18 |
| 43 | 81264 | 18736 | 91650 | 08350 | 9.00046 | 10.99954 | 17 |
| 44 | 81459 | 18541 | 91803 | 08197 | 00174 | 99826 | 16 |
| 45 | 81653 | 18347 | 91957 | 08043 | 00301 | 99699 | 15 |
| 46 | 81846 | 18154 | 92110 | 07890 | 00427 | 99573 | 14 |
| 47 | 82038 | 17962 | 92262 | 07738 | 00553 | 99447 | 13 |
| 48 | 82230 | 17770 | 92414 | 07586 | 00679 | 99321 | 12 |
| 49 | 82420 | 17580 | 92565 | 07435 | 00805 | 99195 | 11 |
| 50 | 8.82610 | 11.17390 | 8.92716 | 11.07284 | 9.00930 | 10.99070 | 10 |
| 51 | 82799 | 17201 | 92866 | 07134 | 01055 | 98945 | 9 |
| 52 | 82987 | 17013 | 93016 | 06984 | 01179 | 98821 | 8 |
| 53 | 83175 | 16825 | 93165 | 06835 | 01303 | 98697 | 7 |
| 54 | 83361 | 16639 | 93313 | 06687 | 01427 | 98573 | 6 |
| 55 | 83547 | 16453 | 93462 | 06538 | 01550 | 98450 | 5 |
| 56 | 83732 | 16268 | 93609 | 06391 | 01673 | 98327 | 4 |
| 57 | 83916 | 16084 | 93756 | 06244 | 01796 | 98204 | 3 |
| 58 | 84100 | 15900 | 93903 | 06097 | 01918 | 98082 | 2 |
| 59 | 84282 | 15718 | 94049 | 05951 | 02040 | 97960 | 1 |
| 60 | 84464 | 15536 | 94195 | 05805 | 02162 | 97838 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 86° | | 85° | | 84° | | |

| ′ | 6° |  | 7° |  | 8° |  | ′ |
|---|---|---|---|---|---|---|---|
|  | Tan | Cotan | Tan | Cotan | Tan | Cotan |  |
| 0 | 9.02162 | 10.97838 | 9.08914 | 10.91086 | 9.14780 | 10.85220 | 60 |
| 1 | 02283 | 97717 | 09019 | 90981 | 14872 | 85128 | 59 |
| 2 | 02404 | 97596 | 09123 | 90877 | 14963 | 85037 | 58 |
| 3 | 02525 | 97475 | 09227 | 90773 | 15054 | 84946 | 57 |
| 4 | 02645 | 97355 | 09330 | 90670 | 15145 | 84855 | 56 |
| 5 | 02766 | 97234 | 09434 | 90566 | 15236 | 84764 | 55 |
| 6 | 02885 | 97115 | 09537 | 90463 | 15327 | 84673 | 54 |
| 7 | 03005 | 96995 | 09640 | 90360 | 15417 | 84583 | 53 |
| 8 | 03124 | 96876 | 09742 | 90258 | 15508 | 84492 | 52 |
| 9 | 03242 | 96758 | 09845 | 90155 | 15598 | 84402 | 51 |
| 10 | 9.03361 | 10.96639 | 9.09947 | 10.90053 | 9.15688 | 10.84312 | 50 |
| 11 | 03479 | 96521 | 10049 | 89951 | 15777 | 84223 | 49 |
| 12 | 03597 | 96403 | 10150 | 89850 | 15867 | 84133 | 48 |
| 13 | 03714 | 96286 | 10252 | 89748 | 15956 | 84044 | 47 |
| 14 | 03832 | 96168 | 10353 | 89647 | 16046 | 83954 | 46 |
| 15 | 03948 | 96052 | 10454 | 89546 | 16135 | 83865 | 45 |
| 16 | 04065 | 95935 | 10555 | 89445 | 16224 | 83776 | 44 |
| 17 | 04181 | 95819 | 10656 | 89344 | 16312 | 83688 | 43 |
| 18 | 04297 | 95703 | 10756 | 89244 | 16401 | 83599 | 42 |
| 19 | 04413 | 95587 | 10856 | 89144 | 16489 | 83511 | 41 |
| 20 | 9.04528 | 10.95472 | 9.10956 | 10.89044 | 9.16577 | 10.83423 | 40 |
| 21 | 04643 | 95357 | 11056 | 88944 | 16665 | 83335 | 39 |
| 22 | 04758 | 95242 | 11155 | 88845 | 16753 | 83247 | 38 |
| 23 | 04873 | 95127 | 11254 | 88746 | 16841 | 83159 | 37 |
| 24 | 04987 | 95013 | 11353 | 88647 | 16928 | 83072 | 36 |
| 25 | 05101 | 94899 | 11452 | 88548 | 17016 | 82984 | 35 |
| 26 | 05214 | 94786 | 11551 | 88449 | 17103 | 82897 | 34 |
| 27 | 05328 | 94672 | 11649 | 88351 | 17190 | 82810 | 33 |
| 28 | 05441 | 94559 | 11747 | 88253 | 17277 | 82723 | 32 |
| 29 | 05553 | 94447 | 11845 | 88155 | 17363 | 82637 | 31 |
| 30 | 9.05666 | 10.94334 | 9.11943 | 10.88057 | 9.17450 | 10.82550 | 30 |
| 31 | 05778 | 94222 | 12040 | 87960 | 17536 | 82464 | 29 |
| 32 | 05890 | 94110 | 12138 | 87862 | 17622 | 82378 | 28 |
| 33 | 06002 | 93998 | 12235 | 87765 | 17708 | 82292 | 27 |
| 34 | 06113 | 93887 | 12332 | 87668 | 17794 | 82206 | 26 |
| 35 | 06224 | 93776 | 12428 | 87572 | 17880 | 82120 | 25 |
| 36 | 06335 | 93665 | 12525 | 87475 | 17965 | 82035 | 24 |
| 37 | 06445 | 93555 | 12621 | 87379 | 18051 | 81949 | 23 |
| 38 | 06556 | 93444 | 12717 | 87283 | 18136 | 81864 | 22 |
| 39 | 06666 | 93334 | 12813 | 87187 | 18221 | 81779 | 21 |
| 40 | 9.06775 | 10.93225 | 9.12909 | 10.87091 | 9.18306 | 10.81694 | 20 |
| 41 | 06885 | 93115 | 13004 | 86996 | 18391 | 81609 | 19 |
| 42 | 06994 | 93006 | 13099 | 86901 | 18475 | 81525 | 18 |
| 43 | 07103 | 92897 | 13194 | 86806 | 18560 | 81440 | 17 |
| 44 | 07211 | 92789 | 13289 | 86711 | 18644 | 81356 | 16 |
| 45 | 07320 | 92680 | 13384 | 86616 | 18728 | 81272 | 15 |
| 46 | 07428 | 92572 | 13478 | 86522 | 18812 | 81188 | 14 |
| 47 | 07536 | 92464 | 13573 | 86427 | 18896 | 81104 | 13 |
| 48 | 07643 | 92357 | 13667 | 86333 | 18979 | 81021 | 12 |
| 49 | 07751 | 92249 | 13761 | 86239 | 19063 | 80937 | 11 |
| 50 | 9.07858 | 10.92142 | 9.13854 | 10.86146 | 9.19146 | 10.80854 | 10 |
| 51 | 07964 | 92036 | 13948 | 86052 | 19229 | 80771 | 9 |
| 52 | 08071 | 91929 | 14041 | 85959 | 19312 | 80688 | 8 |
| 53 | 08177 | 91823 | 14134 | 85866 | 19395 | 80605 | 7 |
| 54 | 08283 | 91717 | 14227 | 85773 | 19478 | 80522 | 6 |
| 55 | 08389 | 91611 | 14320 | 85680 | 19561 | 80439 | 5 |
| 56 | 08495 | 91505 | 14412 | 85588 | 19643 | 80357 | 4 |
| 57 | 08600 | 91400 | 14504 | 85496 | 19725 | 80275 | 3 |
| 58 | 08705 | 91295 | 14597 | 85403 | 19807 | 80193 | 2 |
| 59 | 08810 | 91190 | 14688 | 85312 | 19889 | 80111 | 1 |
| 60 | 08914 | 91086 | 14780 | 85220 | 19971 | 80029 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
|  | 83° |  | 82° |  | 81° |  |  |

## TABLE VIII.—LOG. TANGENTS AND COTANGENTS.

| ′ | 9° |  | 10° |  | 11° |  | ′ |
|---|---|---|---|---|---|---|---|
|  | Tan | Cotan | Tan | Cotan | Tan | Cotan |  |
| 0 | 9.19971 | 10.80029 | 9.24632 | 10.75368 | 9.28865 | 10.71135 | 60 |
| 1 | 20053 | 79947 | 24706 | 75294 | 28933 | 71067 | 59 |
| 2 | 20134 | 79866 | 24779 | 75221 | 29000 | 71000 | 58 |
| 3 | 20216 | 79784 | 24853 | 75147 | 29067 | 70933 | 57 |
| 4 | 20297 | 79703 | 24926 | 75074 | 29134 | 70866 | 56 |
| 5 | 20378 | 79622 | 25000 | 75000 | 29201 | 70799 | 55 |
| 6 | 20459 | 79541 | 25073 | 74927 | 29268 | 70732 | 54 |
| 7 | 20540 | 79460 | 25146 | 74854 | 29335 | 70665 | 53 |
| 8 | 20621 | 79379 | 25219 | 74781 | 29402 | 70598 | 52 |
| 9 | 20701 | 79299 | 25292 | 74708 | 29468 | 70532 | 51 |
| 10 | 9.20782 | 10.79218 | 9.25365 | 10.74635 | 9.29535 | 10.70465 | 50 |
| 11 | 20862 | 79138 | 25437 | 74563 | 29601 | 70399 | 49 |
| 12 | 20942 | 79058 | 25510 | 74490 | 29668 | 70332 | 48 |
| 13 | 21022 | 78978 | 25582 | 74418 | 29734 | 70266 | 47 |
| 14 | 21102 | 78898 | 25655 | 74345 | 29800 | 70200 | 46 |
| 15 | 21182 | 78818 | 25727 | 74273 | 29866 | 70134 | 45 |
| 16 | 21261 | 78739 | 25799 | 74201 | 29932 | 70068 | 44 |
| 17 | 21341 | 78659 | 25871 | 74129 | 29998 | 70002 | 43 |
| 18 | 21420 | 78580 | 25943 | 74057 | 30064 | 69936 | 42 |
| 19 | 21499 | 78501 | 26015 | 73985 | 30130 | 69870 | 41 |
| 20 | 9.21578 | 10.78422 | 9.26086 | 10.73914 | 9.30195 | 10.69805 | 40 |
| 21 | 21657 | 78343 | 26158 | 73842 | 30261 | 69739 | 39 |
| 22 | 21736 | 78264 | 26229 | 73771 | 30326 | 69674 | 38 |
| 23 | 21814 | 78186 | 26301 | 73699 | 30391 | 69609 | 37 |
| 24 | 21893 | 78107 | 26372 | 73628 | 30457 | 69543 | 36 |
| 25 | 21971 | 78029 | 26443 | 73557 | 30522 | 69478 | 35 |
| 26 | 22049 | 77951 | 26514 | 73486 | 30587 | 69413 | 34 |
| 27 | 22127 | 77873 | 26585 | 73415 | 30652 | 69348 | 33 |
| 28 | 22205 | 77795 | 26655 | 73345 | 30717 | 69283 | 32 |
| 29 | 22283 | 77717 | 26726 | 73274 | 30782 | 69218 | 31 |
| 30 | 9.22361 | 10.77639 | 9.26797 | 10.73203 | 9.30846 | 10.69154 | 30 |
| 31 | 22438 | 77562 | 26867 | 73133 | 30911 | 69089 | 29 |
| 32 | 22516 | 77484 | 26937 | 73063 | 30975 | 69025 | 28 |
| 33 | 22593 | 77407 | 27008 | 72992 | 31040 | 68960 | 27 |
| 34 | 22670 | 77330 | 27078 | 72922 | 31104 | 68896 | 26 |
| 35 | 22747 | 77253 | 27148 | 72852 | 31168 | 68832 | 25 |
| 36 | 22824 | 77176 | 27218 | 72782 | 31233 | 68767 | 24 |
| 37 | 22901 | 77099 | 27288 | 72712 | 31297 | 68703 | 23 |
| 38 | 22977 | 77023 | 27357 | 72643 | 31361 | 68639 | 22 |
| 39 | 23054 | 76946 | 27427 | 72573 | 31425 | 68575 | 21 |
| 40 | 9.23130 | 10.76870 | 9.27496 | 10.72504 | 9.31489 | 10.68511 | 20 |
| 41 | 23206 | 76794 | 27566 | 72434 | 31552 | 68448 | 19 |
| 42 | 23283 | 76717 | 27635 | 72365 | 31616 | 68384 | 18 |
| 43 | 23359 | 76641 | 27704 | 72296 | 31679 | 68321 | 17 |
| 44 | 23435 | 76565 | 27773 | 72227 | 31743 | 68257 | 16 |
| 45 | 23510 | 76490 | 27842 | 72158 | 31806 | 68194 | 15 |
| 46 | 23586 | 76414 | 27911 | 72089 | 31870 | 68130 | 14 |
| 47 | 23661 | 76339 | 27980 | 72020 | 31933 | 68067 | 13 |
| 48 | 23737 | 76263 | 28049 | 71951 | 31996 | 68004 | 12 |
| 49 | 23812 | 76188 | 28117 | 71883 | 32059 | 67941 | 11 |
| 50 | 9.23887 | 10.76113 | 9.28186 | 10.71814 | 9.32122 | 10.67878 | 10 |
| 51 | 23962 | 76038 | 28254 | 71746 | 32185 | 67815 | 9 |
| 52 | 24037 | 75963 | 28323 | 71677 | 32248 | 67752 | 8 |
| 53 | 24112 | 75888 | 28391 | 71609 | 32311 | 67689 | 7 |
| 54 | 24186 | 75814 | 28459 | 71541 | 32373 | 67627 | 6 |
| 55 | 24261 | 75739 | 28527 | 71473 | 32436 | 67564 | 5 |
| 56 | 24335 | 75665 | 28595 | 71405 | 32498 | 67502 | 4 |
| 57 | 24410 | 75590 | 28662 | 71338 | 32561 | 67439 | 3 |
| 58 | 24484 | 75516 | 28730 | 71270 | 32623 | 67377 | 2 |
| 59 | 24558 | 75442 | 28798 | 71202 | 32685 | 67315 | 1 |
| 60 | 24632 | 75368 | 28865 | 71135 | 32747 | 67253 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan |  |
|  | 80° |  | 79° |  | 78° |  |  |

| ′ | 12° | | 13° | | 14° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.32747 | 10.67253 | 9.36336 | 10.63664 | 9.39677 | 10.60323 | 60 |
| 1 | 32810 | 67190 | 36394 | 63606 | 39731 | 60269 | 59 |
| 2 | 32872 | 67128 | 36452 | 63548 | 39785 | 60215 | 58 |
| 3 | 32933 | 67067 | 36509 | 63491 | 39838 | 60162 | 57 |
| 4 | 32995 | 67005 | 36566 | 63434 | 39892 | 60108 | 56 |
| 5 | 33057 | 66943 | 36624 | 63376 | 39945 | 60055 | 55 |
| 6 | 33119 | 66881 | 36681 | 63319 | 39999 | 60001 | 54 |
| 7 | 33180 | 66820 | 36738 | 63262 | 40052 | 59948 | 53 |
| 8 | 33242 | 66758 | 36795 | 63205 | 40106 | 59894 | 52 |
| 9 | 33303 | 66697 | 36852 | 63148 | 40159 | 59841 | 51 |
| 10 | 9.33365 | 10.66635 | 9.36909 | 10.63091 | 9.40212 | 10.59788 | 50 |
| 11 | 33426 | 66574 | 36966 | 63034 | 40266 | 59734 | 49 |
| 12 | 33487 | 66513 | 37023 | 62977 | 40319 | 59681 | 48 |
| 13 | 33548 | 66452 | 37080 | 62920 | 40372 | 59628 | 47 |
| 14 | 33609 | 66391 | 37137 | 62863 | 40425 | 59575 | 46 |
| 15 | 33670 | 66330 | 37193 | 62807 | 40478 | 59522 | 45 |
| 16 | 33731 | 66269 | 37250 | 62750 | 40531 | 59469 | 44 |
| 17 | 33792 | 66208 | 37306 | 62694 | 40584 | 59416 | 43 |
| 18 | 33853 | 66147 | 37363 | 62637 | 40636 | 59364 | 42 |
| 19 | 33913 | 66087 | 37419 | 62581 | 40689 | 59311 | 41 |
| 20 | 9.33974 | 10.66026 | 9.37476 | 10.62524 | 9.40742 | 10.59258 | 40 |
| 21 | 34034 | 65966 | 37532 | 62468 | 40795 | 59205 | 39 |
| 22 | 34095 | 65905 | 37588 | 62412 | 40847 | 59153 | 38 |
| 23 | 34155 | 65845 | 37644 | 62356 | 40900 | 59100 | 37 |
| 24 | 34215 | 65785 | 37700 | 62300 | 40952 | 59048 | 36 |
| 25 | 34276 | 65724 | 37756 | 62244 | 41005 | 58995 | 35 |
| 26 | 34336 | 65664 | 37812 | 62188 | 41057 | 58943 | 34 |
| 27 | 34396 | 65604 | 37868 | 62132 | 41109 | 58891 | 33 |
| 28 | 34456 | 65544 | 37924 | 62076 | 41161 | 58839 | 32 |
| 29 | 34516 | 65484 | 37980 | 62020 | 41214 | 58786 | 31 |
| 30 | 9.34576 | 10.65424 | 9.38035 | 10.61965 | 9.41266 | 10.58734 | 30 |
| 31 | 34635 | 65365 | 38091 | 61909 | 41318 | 58682 | 29 |
| 32 | 34695 | 65305 | 38147 | 61853 | 41370 | 58630 | 28 |
| 33 | 34755 | 65245 | 38202 | 61798 | 41422 | 58578 | 27 |
| 34 | 34814 | 65186 | 38257 | 61743 | 41474 | 58526 | 26 |
| 35 | 34874 | 65126 | 38313 | 61687 | 41526 | 58474 | 25 |
| 36 | 34933 | 65067 | 38368 | 61632 | 41578 | 58422 | 24 |
| 37 | 34992 | 65008 | 38423 | 61577 | 41629 | 58371 | 23 |
| 38 | 35051 | 64949 | 38479 | 61521 | 41681 | 58319 | 22 |
| 39 | 35111 | 64889 | 38534 | 61466 | 41733 | 58267 | 21 |
| 40 | 9.35170 | 10.64830 | 9.38589 | 10.61411 | 9.41784 | 10.58216 | 20 |
| 41 | 35229 | 64771 | 38644 | 61356 | 41836 | 58164 | 19 |
| 42 | 35288 | 64712 | 38699 | 61301 | 41887 | 58113 | 18 |
| 43 | 35347 | 64653 | 38754 | 61246 | 41939 | 58061 | 17 |
| 44 | 35405 | 64595 | 38808 | 61192 | 41990 | 58010 | 16 |
| 45 | 35464 | 64536 | 38863 | 61137 | 42041 | 57959 | 15 |
| 46 | 35523 | 64477 | 38918 | 61082 | 42093 | 57907 | 14 |
| 47 | 35581 | 64419 | 38972 | 61028 | 42144 | 57856 | 13 |
| 48 | 35640 | 64360 | 39027 | 60973 | 42195 | 57805 | 12 |
| 49 | 35698 | 64302 | 39082 | 60918 | 42246 | 57754 | 11 |
| 50 | 9.35757 | 10.64243 | 9.39136 | 10.60864 | 9.42297 | 10.57703 | 10 |
| 51 | 35815 | 64185 | 39190 | 60810 | 42348 | 57652 | 9 |
| 52 | 35873 | 64127 | 39245 | 60755 | 42399 | 57601 | 8 |
| 53 | 35931 | 64069 | 39299 | 60701 | 42450 | 57550 | 7 |
| 54 | 35989 | 64011 | 39353 | 60647 | 42501 | 57499 | 6 |
| 55 | 36047 | 63953 | 39407 | 60593 | 42552 | 57448 | 5 |
| 56 | 36105 | 63895 | 39461 | 60539 | 42603 | 57397 | 4 |
| 57 | 36163 | 63837 | 39515 | 60485 | 42653 | 57347 | 3 |
| 58 | 36221 | 63779 | 39569 | 60431 | 42704 | 57296 | 2 |
| 59 | 36279 | 63721 | 39623 | 60377 | 42755 | 57245 | 1 |
| 60 | 36336 | 63664 | 39677 | 60323 | 42805 | 57195 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 77° | | 76° | | 75° | | |

| ′ | 15° | | 16° | | 17° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.42805 | 10.57195 | 9.45750 | 10.54250 | 9.48534 | 10.51466 | 60 |
| 1 | 42856 | 57144 | 45797 | 54203 | 48579 | 51421 | 59 |
| 2 | 42906 | 57094 | 45845 | 54155 | 48624 | 51376 | 58 |
| 3 | 42957 | 57043 | 45892 | 54108 | 48669 | 51331 | 57 |
| 4 | 43007 | 56993 | 45940 | 54060 | 48714 | 51286 | 56 |
| 5 | 43057 | 56943 | 45987 | 54013 | 48759 | 51241 | 55 |
| 6 | 43108 | 56892 | 46035 | 53965 | 48804 | 51196 | 54 |
| 7 | 43158 | 56842 | 46082 | 53918 | 48849 | 51151 | 53 |
| 8 | 43208 | 56792 | 46130 | 53870 | 48894 | 51106 | 52 |
| 9 | 43258 | 56742 | 46177 | 53823 | 48939 | 51061 | 51 |
| 10 | 9.43308 | 10.56692 | 9.46224 | 10.53776 | 9.48984 | 10.51016 | 50 |
| 11 | 43358 | 56642 | 46271 | 53729 | 49029 | 50971 | 49 |
| 12 | 43408 | 56592 | 46319 | 53681 | 49073 | 50927 | 48 |
| 13 | 43458 | 56542 | 46366 | 53634 | 49118 | 50882 | 47 |
| 14 | 43508 | 56492 | 46413 | 53587 | 49163 | 50837 | 46 |
| 15 | 43558 | 56442 | 46460 | 53540 | 49207 | 50793 | 45 |
| 16 | 43607 | 56393 | 46507 | 53493 | 49252 | 50748 | 44 |
| 17 | 43657 | 56343 | 46554 | 53446 | 49296 | 50704 | 43 |
| 18 | 43707 | 56293 | 46601 | 53399 | 49341 | 50659 | 42 |
| 19 | 43756 | 56244 | 46648 | 53352 | 49385 | 50615 | 41 |
| 20 | 9.43806 | 10.56194 | 9.46694 | 10.53306 | 9.49430 | 10.50570 | 40 |
| 21 | 43855 | 56145 | 46741 | 53259 | 49474 | 50526 | 39 |
| 22 | 43905 | 56095 | 46788 | 53212 | 49519 | 50481 | 38 |
| 23 | 43954 | 56046 | 46835 | 53165 | 49563 | 50437 | 37 |
| 24 | 44004 | 55996 | 46881 | 53119 | 49607 | 50393 | 36 |
| 25 | 44053 | 55947 | 46928 | 53072 | 49652 | 50348 | 35 |
| 26 | 44102 | 55898 | 46975 | 53025 | 49696 | 50304 | 34 |
| 27 | 44151 | 55849 | 47021 | 52979 | 49740 | 50260 | 33 |
| 28 | 44201 | 55799 | 47068 | 52932 | 49784 | 50216 | 32 |
| 29 | 44250 | 55750 | 47114 | 52886 | 49828 | 50172 | 31 |
| 30 | 9.44299 | 10.55701 | 9.47160 | 10.52840 | 9.49872 | 10.50128 | 30 |
| 31 | 44348 | 55652 | 47207 | 52793 | 49916 | 50084 | 29 |
| 32 | 44397 | 55603 | 47253 | 52747 | 49960 | 50040 | 28 |
| 33 | 44446 | 55554 | 47299 | 52701 | 50004 | 49996 | 27 |
| 34 | 44495 | 55505 | 47346 | 52654 | 50048 | 49952 | 26 |
| 35 | 44544 | 55456 | 47392 | 52608 | 50092 | 49908 | 25 |
| 36 | 44592 | 55408 | 47438 | 52562 | 50136 | 49864 | 24 |
| 37 | 44641 | 55359 | 47484 | 52516 | 50180 | 49820 | 23 |
| 38 | 44690 | 55310 | 47530 | 52470 | 50223 | 49777 | 22 |
| 39 | 44738 | 55262 | 47576 | 52424 | 50267 | 49733 | 21 |
| 40 | 9.44787 | 10.55213 | 9.47622 | 10.52378 | 9.50311 | 10.49689 | 20 |
| 41 | 44836 | 55164 | 47668 | 52332 | 50355 | 49645 | 19 |
| 42 | 44884 | 55116 | 47714 | 52286 | 50398 | 49602 | 18 |
| 43 | 44933 | 55067 | 47760 | 52240 | 50442 | 49558 | 17 |
| 44 | 44981 | 55019 | 47806 | 52194 | 50485 | 49515 | 16 |
| 45 | 45029 | 54971 | 47852 | 52148 | 50529 | 49471 | 15 |
| 46 | 45078 | 54922 | 47897 | 52103 | 50572 | 49428 | 14 |
| 47 | 45126 | 54874 | 47943 | 52057 | 50616 | 49384 | 13 |
| 48 | 45174 | 54826 | 47989 | 52011 | 50659 | 49341 | 12 |
| 49 | 45222 | 54778 | 48035 | 51965 | 50703 | 49297 | 11 |
| 50 | 9.45271 | 10.54729 | 9.48080 | 10.51920 | 9.50746 | 10.49254 | 10 |
| 51 | 45319 | 54681 | 48126 | 51874 | 50789 | 49211 | 9 |
| 52 | 45367 | 54633 | 48171 | 51829 | 50833 | 49167 | 8 |
| 53 | 45415 | 54585 | 48217 | 51783 | 50876 | 49124 | 7 |
| 54 | 45463 | 54537 | 48262 | 51738 | 50919 | 49081 | 6 |
| 55 | 45511 | 54489 | 48307 | 51693 | 50962 | 49038 | 5 |
| 56 | 45559 | 54441 | 48353 | 51647 | 51005 | 48995 | 4 |
| 57 | 45606 | 54394 | 48398 | 51602 | 51048 | 48952 | 3 |
| 58 | 45654 | 54346 | 48443 | 51557 | 51092 | 48908 | 2 |
| 59 | 45702 | 54298 | 48489 | 51511 | 51135 | 48865 | 1 |
| 60 | 45750 | 54250 | 48534 | 51466 | 51178 | 48822 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 74° | | 73° | | 72° | | |

| ′ | 18° |  | 19° |  | 20° |  | ′ |
|---|---|---|---|---|---|---|---|
|  | Tan | Cotan | Tan | Cotan | Tan | Cotan |  |
| 0 | 9.51178 | 10.48822 | 9.53697 | 10.46303 | 9.56107 | 10.43893 | 60 |
| 1 | 51221 | 48779 | 53738 | 46262 | 56146 | 43854 | 59 |
| 2 | 51264 | 48736 | 53779 | 46221 | 56185 | 43815 | 58 |
| 3 | 51306 | 48694 | 53820 | 46180 | 56224 | 43776 | 57 |
| 4 | 51349 | 48651 | 53861 | 46139 | 56264 | 43736 | 56 |
| 5 | 51392 | 48608 | 53902 | 46098 | 56303 | 43697 | 55 |
| 6 | 51435 | 48565 | 53943 | 46057 | 56342 | 43658 | 54 |
| 7 | 51478 | 48522 | 53984 | 46016 | 56381 | 43619 | 53 |
| 8 | 51520 | 48480 | 54025 | 45975 | 56420 | 43580 | 52 |
| 9 | 51563 | 48437 | 54065 | 45935 | 56459 | 43541 | 51 |
| 10 | 9.51606 | 10.48394 | 9.54106 | 10.45894 | 9.56498 | 10.43502 | 50 |
| 11 | 51648 | 48352 | 54147 | 45853 | 56537 | 43463 | 49 |
| 12 | 51691 | 48309 | 54187 | 45813 | 56576 | 43424 | 48 |
| 13 | 51734 | 48266 | 54228 | 45772 | 56615 | 43385 | 47 |
| 14 | 51776 | 48224 | 54269 | 45731 | 56654 | 43346 | 46 |
| 15 | 51819 | 48181 | 54309 | 45691 | 56693 | 43307 | 45 |
| 16 | 51861 | 48139 | 54350 | 45650 | 56732 | 43268 | 44 |
| 17 | 51903 | 48097 | 54390 | 45610 | 56771 | 43229 | 43 |
| 18 | 51946 | 48054 | 54431 | 45569 | 56810 | 43190 | 42 |
| 19 | 51988 | 48012 | 54471 | 45529 | 56849 | 43151 | 41 |
| 20 | 9.52031 | 10.47969 | 9.54512 | 10.45488 | 9.56887 | 10.43113 | 40 |
| 21 | 52073 | 47927 | 54552 | 45448 | 56926 | 43074 | 39 |
| 22 | 52115 | 47885 | 54593 | 45407 | 56965 | 43035 | 38 |
| 23 | 52157 | 47843 | 54633 | 45367 | 57004 | 42996 | 37 |
| 24 | 52200 | 47800 | 54673 | 45327 | 57042 | 42958 | 36 |
| 25 | 52242 | 47758 | 54714 | 45286 | 57081 | 42919 | 35 |
| 26 | 52284 | 47716 | 54754 | 45246 | 57120 | 42880 | 34 |
| 27 | 52326 | 47674 | 54794 | 45206 | 57158 | 42842 | 33 |
| 28 | 52368 | 47632 | 54835 | 45165 | 57197 | 42803 | 32 |
| 29 | 52410 | 47590 | 54875 | 45125 | 57235 | 42765 | 31 |
| 30 | 9.52452 | 10.47548 | 9.54915 | 10.45085 | 9.57274 | 10.42726 | 30 |
| 31 | 52494 | 47506 | 54955 | 45045 | 57312 | 42688 | 29 |
| 32 | 52536 | 47464 | 54995 | 45005 | 57351 | 42649 | 28 |
| 33 | 52578 | 47422 | 55035 | 44965 | 57389 | 42611 | 27 |
| 34 | 52620 | 47380 | 55075 | 44925 | 57428 | 42572 | 26 |
| 35 | 52661 | 47339 | 55115 | 44885 | 57466 | 42534 | 25 |
| 36 | 52703 | 47297 | 55155 | 44845 | 57504 | 42496 | 24 |
| 37 | 52745 | 47255 | 55195 | 44805 | 57543 | 42457 | 23 |
| 38 | 52787 | 47213 | 55235 | 44765 | 57581 | 42419 | 22 |
| 39 | 52829 | 47171 | 55275 | 44725 | 57619 | 42381 | 21 |
| 40 | 9.52870 | 10.47130 | 9.55815 | 10.44685 | 9.57658 | 10.42342 | 20 |
| 41 | 52912 | 47088 | 55355 | 44645 | 57696 | 42304 | 19 |
| 42 | 52953 | 47047 | 55395 | 44605 | 57734 | 42266 | 18 |
| 43 | 52995 | 47005 | 55434 | 44566 | 57772 | 42228 | 17 |
| 44 | 53037 | 46963 | 55474 | 44526 | 57810 | 42190 | 16 |
| 45 | 53078 | 46922 | 55514 | 44486 | 57849 | 42151 | 15 |
| 46 | 53120 | 46880 | 55554 | 44446 | 57887 | 42113 | 14 |
| 47 | 53161 | 46839 | 55593 | 44407 | 57925 | 42075 | 13 |
| 48 | 53202 | 46798 | 55633 | 44367 | 57963 | 42037 | 12 |
| 49 | 53244 | 40756 | 55673 | 44327 | 58001 | 41999 | 11 |
| 50 | 9.53285 | 10.46715 | 9.55712 | 10.44288 | 9.58039 | 10.41961 | 10 |
| 51 | 53327 | 46673 | 55752 | 44248 | 58077 | 41923 | 9 |
| 52 | 53368 | 46632 | 55791 | 44209 | 58115 | 41885 | 8 |
| 53 | 53409 | 46591 | 55831 | 44169 | 58153 | 41847 | 7 |
| 54 | 53450 | 46550 | 55870 | 44130 | 58191 | 41809 | 6 |
| 55 | 53492 | 46508 | 55910 | 44090 | 58229 | 41771 | 5 |
| 56 | 53533 | 46467 | 55949 | 44051 | 58267 | 41733 | 4 |
| 57 | 53574 | 46426 | 55989 | 44011 | 58304 | 41696 | 3 |
| 58 | 53615 | 46385 | 56028 | 43972 | 58342 | 41658 | 2 |
| 59 | 53656 | 46344 | 56067 | 43933 | 58380 | 41620 | 1 |
| 60 | 53697 | 46303 | 56107 | 43893 | 58418 | 41582 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
|  | 71° |  | 70° |  | 69° |  |  |

| ′ | 21° | | 22° | | 23° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.58418 | 10.41582 | 9.60641 | 10.39359 | 9.62785 | 10.37215 | 60 |
| 1 | 58455 | 41545 | 60677 | 39323 | 62820 | 37180 | 59 |
| 2 | 58493 | 41507 | 60714 | 39286 | 62855 | 37145 | 58 |
| 3 | 58531 | 41469 | 60750 | 39250 | 62890 | 37110 | 57 |
| 4 | 58569 | 41431 | 60786 | 39214 | 62926 | 37074 | 56 |
| 5 | 58606 | 41394 | 60823 | 39177 | 62961 | 37039 | 55 |
| 6 | 58644 | 41356 | 60859 | 39141 | 62996 | 37004 | 54 |
| 7 | 58681 | 41319 | 60895 | 39105 | 63031 | 36969 | 53 |
| 8 | 58719 | 41281 | 60931 | 39069 | 63066 | 36934 | 52 |
| 9 | 58757 | 41243 | 60967 | 39033 | 63101 | 36899 | 51 |
| 10 | 9.58794 | 10.41206 | 9.61004 | 10.38996 | 9.63135 | 10.36865 | 50 |
| 11 | 58832 | 41168 | 61040 | 38960 | 63170 | 36830 | 49 |
| 12 | 58869 | 41131 | 61076 | 38924 | 63205 | 36795 | 48 |
| 13 | 58907 | 41093 | 61112 | 38888 | 63240 | 36760 | 47 |
| 14 | 58944 | 41056 | 61148 | 38852 | 63275 | 36725 | 46 |
| 15 | 58981 | 41019 | 61184 | 38816 | 63310 | 36690 | 45 |
| 16 | 59019 | 40981 | 61220 | 38780 | 63345 | 36655 | 44 |
| 17 | 59056 | 40944 | 61256 | 38744 | 63379 | 36621 | 43 |
| 18 | 59094 | 40906 | 61292 | 38708 | 63414 | 36586 | 42 |
| 19 | 59131 | 40869 | 61328 | 38672 | 63449 | 36551 | 41 |
| 20 | 9.59168 | 10.40832 | 9.61364 | 10.38636 | 9.63484 | 10.36516 | 40 |
| 21 | 59205 | 40795 | 61400 | 38600 | 63519 | 36481 | 39 |
| 22 | 59243 | 40757 | 61436 | 38564 | 63553 | 36447 | 38 |
| 23 | 59280 | 40720 | 61472 | 38528 | 63588 | 36412 | 37 |
| 24 | 59317 | 40683 | 61508 | 38492 | 63623 | 36377 | 36 |
| 25 | 59354 | 40646 | 61544 | 38456 | 63657 | 36343 | 35 |
| 26 | 59391 | 40609 | 61579 | 38421 | 63692 | 36308 | 34 |
| 27 | 59429 | 40571 | 61615 | 38385 | 63726 | 36274 | 33 |
| 28 | 59466 | 40534 | 61651 | 38349 | 63761 | 36239 | 32 |
| 29 | 59503 | 40497 | 61687 | 38313 | 63796 | 36204 | 31 |
| 30 | 9.59540 | 10.40460 | 9.61722 | 10.38278 | 9.63830 | 10.36170 | 30 |
| 31 | 59577 | 40423 | 61758 | 38242 | 63865 | 36135 | 29 |
| 32 | 59614 | 40386 | 61794 | 38206 | 63899 | 36101 | 28 |
| 33 | 59651 | 40349 | 61830 | 38170 | 63934 | 36066 | 27 |
| 34 | 59688 | 40312 | 61865 | 38135 | 63968 | 36032 | 26 |
| 35 | 59725 | 40275 | 61901 | 38099 | 64003 | 35997 | 25 |
| 36 | 59762 | 40238 | 61936 | 38064 | 64037 | 35963 | 24 |
| 37 | 59799 | 40201 | 61972 | 38028 | 64072 | 35928 | 23 |
| 38 | 59835 | 40165 | 62008 | 37992 | 64106 | 35894 | 22 |
| 39 | 59872 | 40128 | 62043 | 37957 | 64140 | 35860 | 21 |
| 40 | 9.59909 | 10.40091 | 9.62079 | 10.37921 | 9.64175 | 10.35825 | 20 |
| 41 | 59946 | 40054 | 62114 | 37886 | 64209 | 35791 | 19 |
| 42 | 59983 | 40017 | 62150 | 37850 | 64243 | 35757 | 18 |
| 43 | 60019 | 39981 | 62185 | 37815 | 64278 | 35722 | 17 |
| 44 | 60056 | 39944 | 62221 | 37779 | 64312 | 35688 | 16 |
| 45 | 60093 | 39907 | 62256 | 37744 | 64346 | 35654 | 15 |
| 46 | 60130 | 39870 | 62292 | 37708 | 64381 | 35619 | 14 |
| 47 | 60166 | 39834 | 62327 | 37673 | 64415 | 35585 | 13 |
| 48 | 60203 | 39797 | 62362 | 37638 | 64449 | 35551 | 12 |
| 49 | 60240 | 39760 | 62398 | 37602 | 64483 | 35517 | 11 |
| 50 | 9.60276 | 10.39724 | 9.62433 | 10.37567 | 9.64517 | 10.35483 | 10 |
| 51 | 60313 | 39687 | 62468 | 37532 | 64552 | 35448 | 9 |
| 52 | 60349 | 39651 | 62504 | 37496 | 64586 | 35414 | 8 |
| 53 | 60386 | 39614 | 62539 | 37461 | 64620 | 35380 | 7 |
| 54 | 60422 | 39578 | 62574 | 37426 | 64654 | 35346 | 6 |
| 55 | 60459 | 39541 | 62609 | 37391 | 64688 | 35312 | 5 |
| 56 | 60495 | 39505 | 62645 | 37355 | 64722 | 35278 | 4 |
| 57 | 60532 | 39468 | 62680 | 37320 | 64756 | 35244 | 3 |
| 58 | 60568 | 39432 | 62715 | 37285 | 64790 | 35210 | 2 |
| 59 | 60605 | 39395 | 62750 | 37250 | 64824 | 35176 | 1 |
| 60 | 60641 | 39359 | 62785 | 37215 | 64858 | 35142 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 68° | | 67° | | 66° | | |

| ′ | 24° | | 25° | | 26° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.64858 | 10.35142 | 9.66867 | 10.33133 | 9.68818 | 10.31182 | 60 |
| 1 | 64892 | 35108 | 66900 | 33100 | 68850 | 31150 | 59 |
| 2 | 64926 | 35074 | 66933 | 33067 | 68882 | 31118 | 58 |
| 3 | 64960 | 35040 | 66966 | 33034 | 68914 | 31086 | 57 |
| 4 | 64994 | 35006 | 66999 | 33001 | 68946 | 31054 | 56 |
| 5 | 65028 | 34972 | 67032 | 32968 | 68978 | 31022 | 55 |
| 6 | 65062 | 34938 | 67065 | 32935 | 69010 | 30990 | 54 |
| 7 | 65096 | 34904 | 67098 | 32902 | 69042 | 30958 | 53 |
| 8 | 65130 | 34870 | 67131 | 32869 | 69074 | 30926 | 52 |
| 9 | 65164 | 34836 | 67163 | 32837 | 69106 | 30894 | 51 |
| 10 | 9.65197 | 10.34803 | 9.67196 | 10.32804 | 9.69138 | 10.30862 | 50 |
| 11 | 65231 | 34769 | 67229 | 32771 | 69170 | 30830 | 49 |
| 12 | 65265 | 34735 | 67262 | 32738 | 69202 | 30798 | 48 |
| 13 | 65299 | 34701 | 67295 | 32705 | 69234 | 30766 | 47 |
| 14 | 65333 | 34667 | 67327 | 32673 | 69266 | 30734 | 46 |
| 15 | 65366 | 34634 | 67360 | 32640 | 69298 | 30702 | 45 |
| 16 | 65400 | 34600 | 67393 | 32607 | 69329 | 30671 | 44 |
| 17 | 65434 | 34566 | 67426 | 32574 | 69361 | 30639 | 43 |
| 18 | 65467 | 34533 | 67458 | 32542 | 69393 | 30607 | 42 |
| 19 | 65501 | 34499 | 67491 | 32509 | 69425 | 30575 | 41 |
| 20 | 9.65535 | 10.34465 | 9.67524 | 10.32476 | 9.69457 | 10.30543 | 40 |
| 21 | 65568 | 34432 | 67556 | 32444 | 69488 | 30512 | 39 |
| 22 | 65602 | 34398 | 67589 | 32411 | 69520 | 30480 | 38 |
| 23 | 65636 | 34364 | 67622 | 32378 | 69552 | 30448 | 37 |
| 24 | 65669 | 34331 | 67654 | 32346 | 69584 | 30416 | 36 |
| 25 | 65703 | 34297 | 67687 | 32313 | 69615 | 30385 | 35 |
| 26 | 65736 | 34264 | 67719 | 32281 | 69647 | 30353 | 34 |
| 27 | 65770 | 34230 | 67752 | 32248 | 69679 | 30321 | 33 |
| 28 | 65803 | 34197 | 67785 | 32215 | 69710 | 30290 | 32 |
| 29 | 65837 | 34163 | 67817 | 32183 | 69742 | 30258 | 31 |
| 30 | 9.65870 | 10.34130 | 9.67850 | 10.32150 | 9.69774 | 10.30226 | 30 |
| 31 | 65904 | 34096 | 67882 | 32118 | 69805 | 30195 | 29 |
| 32 | 65937 | 34063 | 67915 | 32085 | 69837 | 30163 | 28 |
| 33 | 65971 | 34029 | 67947 | 32053 | 69868 | 30132 | 27 |
| 34 | 66004 | 33996 | 67980 | 32020 | 69900 | 30100 | 26 |
| 35 | 66038 | 33962 | 68012 | 31988 | 69932 | 30068 | 25 |
| 36 | 66071 | 33929 | 68044 | 31956 | 69963 | 30037 | 24 |
| 37 | 66104 | 33896 | 68077 | 31923 | 69995 | 30005 | 23 |
| 38 | 66138 | 33862 | 68109 | 31891 | 70026 | 29974 | 22 |
| 39 | 66171 | 33829 | 68142 | 31858 | 70058 | 29942 | 21 |
| 40 | 9.66204 | 10.33796 | 9.68174 | 10.31826 | 9.70089 | 10.29911 | 20 |
| 41 | 66238 | 33762 | 68206 | 31794 | 70121 | 29879 | 19 |
| 42 | 66271 | 33729 | 68239 | 31761 | 70152 | 29848 | 18 |
| 43 | 66304 | 33696 | 68271 | 31729 | 70184 | 29816 | 17 |
| 44 | 66337 | 33663 | 68303 | 31697 | 70215 | 29785 | 16 |
| 45 | 66371 | 33629 | 68336 | 31664 | 70247 | 29753 | 15 |
| 46 | 66404 | 33596 | 68368 | 31632 | 70278 | 29722 | 14 |
| 47 | 66437 | 33563 | 68400 | 31600 | 70309 | 29691 | 13 |
| 48 | 66470 | 33530 | 68432 | 31568 | 70341 | 29659 | 12 |
| 49 | 66503 | 33497 | 68465 | 31535 | 70372 | 29628 | 11 |
| 50 | 9.66537 | 10.33463 | 9.68497 | 10.31503 | 9.70404 | 10.29596 | 10 |
| 51 | 66570 | 33430 | 68529 | 31471 | 70435 | 29565 | 9 |
| 52 | 66603 | 33397 | 68561 | 31439 | 70466 | 29534 | 8 |
| 53 | 66636 | 33364 | 68593 | 31407 | 70498 | 29502 | 7 |
| 54 | 66669 | 33331 | 68626 | 31374 | 70529 | 29471 | 6 |
| 55 | 66702 | 33298 | 68658 | 31342 | 70560 | 29440 | 5 |
| 56 | 66735 | 33265 | 68690 | 31310 | 70592 | 29408 | 4 |
| 57 | 66768 | 33232 | 68722 | 31278 | 70623 | 29377 | 3 |
| 58 | 66801 | 33199 | 68754 | 31246 | 70654 | 29346 | 2 |
| 59 | 66834 | 33166 | 68786 | 31214 | 70685 | 29315 | 1 |
| 60 | 66867 | 33133 | 68818 | 31182 | 70717 | 29283 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 65° | | 64° | | 63° | | |

| ′ | 27° |  | 28° |  | 29° |  | ′ |
|---|---|---|---|---|---|---|---|
|  | Tan | Cotan | Tan | Cotan | Tan | Cotan |  |
| 0 | 9.70717 | 10.29283 | 9.72567 | 10.27433 | 9.74375 | 10.25625 | 60 |
| 1 | 70748 | 29252 | 72598 | 27402 | 74405 | 25595 | 59 |
| 2 | 70779 | 29221 | 72628 | 27372 | 74435 | 25565 | 58 |
| 3 | 70810 | 29190 | 72659 | 27341 | 74465 | 25535 | 57 |
| 4 | 70841 | 29159 | 72689 | 27311 | 74494 | 25506 | 56 |
| 5 | 70873 | 29127 | 72720 | 27280 | 74524 | 25476 | 55 |
| 6 | 70904 | 29096 | 72750 | 27250 | 74554 | 25446 | 54 |
| 7 | 70935 | 29065 | 72780 | 27220 | 74583 | 25417 | 53 |
| 8 | 70966 | 29034 | 72811 | 27189 | 74613 | 25387 | 52 |
| 9 | 70997 | 29003 | 72841 | 27159 | 74643 | 25357 | 51 |
| 10 | 9.71028 | 10.28972 | 9.72872 | 10.27128 | 9.74673 | 10.25327 | 50 |
| 11 | 71059 | 28941 | 72902 | 27098 | 74702 | 25298 | 49 |
| 12 | 71090 | 28910 | 72932 | 27068 | 74732 | 25268 | 48 |
| 13 | 71121 | 28879 | 72963 | 27037 | 74762 | 25238 | 47 |
| 14 | 71153 | 28847 | 72993 | 27007 | 74791 | 25209 | 46 |
| 15 | 71184 | 28816 | 73023 | 26977 | 74821 | 25179 | 45 |
| 16 | 71215 | 28785 | 73054 | 26946 | 74851 | 25149 | 44 |
| 17 | 71246 | 28754 | 73084 | 26916 | 74880 | 25120 | 43 |
| 18 | 71277 | 28723 | 73114 | 26886 | 74910 | 25090 | 42 |
| 19 | 71308 | 28692 | 73144 | 26856 | 74939 | 25061 | 41 |
| 20 | 9.71339 | 10.28661 | 9.73175 | 10.26825 | 9.74969 | 10.25031 | 40 |
| 21 | 71370 | 28630 | 73205 | 26795 | 74998 | 25002 | 39 |
| 22 | 71401 | 28599 | 73235 | 26765 | 75028 | 24972 | 38 |
| 23 | 71431 | 28569 | 73265 | 26735 | 75058 | 24942 | 37 |
| 24 | 71462 | 28538 | 73295 | 26705 | 75087 | 24913 | 36 |
| 25 | 71493 | 28507 | 73326 | 26674 | 75117 | 24883 | 35 |
| 26 | 71524 | 28476 | 73356 | 26644 | 75146 | 24854 | 34 |
| 27 | 71555 | 28445 | 73386 | 26614 | 75176 | 24824 | 33 |
| 28 | 71586 | 28414 | 73416 | 26584 | 75205 | 24795 | 32 |
| 29 | 71617 | 28383 | 73446 | 26554 | 75235 | 24765 | 31 |
| 30 | 9.71648 | 10.28352 | 9.73476 | 10.26524 | 9.75264 | 10.24736 | 30 |
| 31 | 71679 | 28321 | 73507 | 26493 | 75294 | 24706 | 29 |
| 32 | 71709 | 28291 | 73537 | 26463 | 75323 | 24677 | 28 |
| 33 | 71740 | 28260 | 73567 | 26433 | 75353 | 24647 | 27 |
| 34 | 71771 | 28229 | 73597 | 26403 | 75382 | 24618 | 26 |
| 35 | 71802 | 28198 | 73627 | 26373 | 75411 | 24589 | 25 |
| 36 | 71833 | 28167 | 73657 | 26343 | 75441 | 24559 | 24 |
| 37 | 71863 | 28137 | 73687 | 26313 | 75470 | 24530 | 23 |
| 38 | 71894 | 28106 | 73717 | 26283 | 75500 | 24500 | 22 |
| 39 | 71925 | 28075 | 73747 | 26253 | 75529 | 24471 | 21 |
| 40 | 9.71955 | 10.28045 | 9.73777 | 10.26223 | 9.75558 | 10.24442 | 20 |
| 41 | 71986 | 28014 | 73807 | 26193 | 75588 | 24412 | 19 |
| 42 | 72017 | 27983 | 73837 | 26163 | 75617 | 24383 | 18 |
| 43 | 72048 | 27952 | 73867 | 26133 | 75647 | 24353 | 17 |
| 44 | 72078 | 27922 | 73897 | 26103 | 75676 | 24324 | 16 |
| 45 | 72109 | 27891 | 73927 | 26073 | 75705 | 24295 | 15 |
| 46 | 72140 | 27860 | 73957 | 26043 | 75735 | 24265 | 14 |
| 47 | 72170 | 27830 | 73987 | 26013 | 75764 | 24236 | 13 |
| 48 | 72201 | 27799 | 74017 | 25983 | 75793 | 24207 | 12 |
| 49 | 72231 | 27769 | 74047 | 25953 | 75822 | 24178 | 11 |
| 50 | 9.72262 | 10.27738 | 9.74077 | 10.25923 | 9.75852 | 10.24148 | 10 |
| 51 | 72293 | 27707 | 74107 | 25893 | 75881 | 24119 | 9 |
| 52 | 72323 | 27677 | 74137 | 25863 | 75910 | 24090 | 8 |
| 53 | 72354 | 27646 | 74166 | 25834 | 75939 | 24061 | 7 |
| 54 | 72384 | 27616 | 74196 | 25804 | 75969 | 24031 | 6 |
| 55 | 72415 | 27585 | 74226 | 25774 | 75998 | 24002 | 5 |
| 56 | 72445 | 27555 | 74256 | 25744 | 76027 | 23973 | 4 |
| 57 | 72476 | 27524 | 74286 | 25714 | 76056 | 23944 | 3 |
| 58 | 72506 | 27494 | 74316 | 25684 | 76086 | 23914 | 2 |
| 59 | 72537 | 27463 | 74345 | 25655 | 76115 | 23885 | 1 |
| 60 | 72567 | 27433 | 74375 | 25625 | 76144 | 23856 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
|  | 62° |  | 61° |  | 60° |  |  |

| ′ | 30° | | 31° | | 32° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.76144 | 10.23856 | 9.77877 | 10.22123 | 9.79579 | 10.20421 | 60 |
| 1 | 76173 | 23827 | 77906 | 22094 | 79607 | 20393 | 59 |
| 2 | 76202 | 23798 | 77935 | 22065 | 79635 | 20365 | 58 |
| 3 | 76231 | 23769 | 77963 | 22037 | 79663 | 20337 | 57 |
| 4 | 76261 | 23739 | 77992 | 22008 | 79691 | 20309 | 56 |
| 5 | 76290 | 23710 | 78020 | 21980 | 79719 | 20281 | 55 |
| 6 | 76319 | 23681 | 78049 | 21951 | 79747 | 20253 | 54 |
| 7 | 76348 | 23652 | 78077 | 21923 | 79776 | 20224 | 53 |
| 8 | 76377 | 23623 | 78106 | 21894 | 79804 | 20196 | 52 |
| 9 | 76406 | 23594 | 78135 | 21865 | 79832 | 20168 | 51 |
| 10 | 9.76435 | 10.23565 | 9.78163 | 10.21837 | 9.79860 | 10.20140 | 50 |
| 11 | 76464 | 23536 | 78192 | 21808 | 79888 | 20112 | 49 |
| 12 | 76493 | 23507 | 78220 | 21780 | 79916 | 20084 | 48 |
| 13 | 76522 | 23478 | 78249 | 21751 | 79944 | 20056 | 47 |
| 14 | 76551 | 23449 | 78277 | 21723 | 79972 | 20028 | 46 |
| 15 | 76580 | 23420 | 78306 | 21694 | 80000 | 20000 | 45 |
| 16 | 76609 | 23391 | 78334 | 21666 | 80028 | 19972 | 44 |
| 17 | 76639 | 23361 | 78363 | 21637 | 80056 | 19944 | 43 |
| 18 | 76668 | 23332 | 78391 | 21609 | 80084 | 19916 | 42 |
| 19 | 76697 | 23303 | 78419 | 21581 | 80112 | 19888 | 41 |
| 20 | 9.76725 | 10.23275 | 9.78448 | 10.21552 | 9.80140 | 10.19860 | 40 |
| 21 | 76754 | 23246 | 78476 | 21524 | 80168 | 19832 | 39 |
| 22 | 76783 | 23217 | 78505 | 21495 | 80195 | 19805 | 38 |
| 23 | 76812 | 23188 | 78533 | 21467 | 80223 | 19777 | 37 |
| 24 | 76841 | 23159 | 78562 | 21438 | 80251 | 19749 | 36 |
| 25 | 76870 | 23130 | 78590 | 21410 | 80279 | 19721 | 35 |
| 26 | 76899 | 23101 | 78618 | 21382 | 80307 | 19693 | 34 |
| 27 | 76928 | 23072 | 78647 | 21353 | 80335 | 19665 | 33 |
| 28 | 76957 | 23043 | 78675 | 21325 | 80363 | 19637 | 32 |
| 29 | 76986 | 23014 | 78704 | 21296 | 80391 | 19609 | 31 |
| 30 | 9.77015 | 10.22985 | 9.78732 | 10.21268 | 9.80419 | 10.19581 | 30 |
| 31 | 77044 | 22956 | 78760 | 21240 | 80447 | 19553 | 29 |
| 32 | 77073 | 22927 | 78789 | 21211 | 80474 | 19526 | 28 |
| 33 | 77101 | 22899 | 78817 | 21183 | 80502 | 19498 | 27 |
| 34 | 77130 | 22870 | 78845 | 21155 | 80530 | 19470 | 26 |
| 35 | 77159 | 22841 | 78874 | 21126 | 80558 | 19442 | 25 |
| 36 | 77188 | 22812 | 78902 | 21098 | 80586 | 19414 | 24 |
| 37 | 77217 | 22783 | 78930 | 21070 | 80614 | 19386 | 23 |
| 38 | 77246 | 22754 | 78959 | 21041 | 80642 | 19358 | 22 |
| 39 | 77274 | 22726 | 78987 | 21013 | 80669 | 19331 | 21 |
| 40 | 9.77303 | 10.22697 | 9.79015 | 10.20985 | 9.80697 | 10.19303 | 20 |
| 41 | 77332 | 22668 | 79043 | 20957 | 80725 | 19275 | 19 |
| 42 | 77361 | 22639 | 79072 | 20928 | 80753 | 19247 | 18 |
| 43 | 77390 | 22610 | 79100 | 20900 | 80781 | 19219 | 17 |
| 44 | 77418 | 22582 | 79128 | 20872 | 80808 | 19192 | 16 |
| 45 | 77447 | 22553 | 79156 | 20844 | 80836 | 19164 | 15 |
| 46 | 77476 | 22524 | 79185 | 20815 | 80864 | 19136 | 14 |
| 47 | 77505 | 22495 | 79213 | 20787 | 80892 | 19108 | 13 |
| 48 | 77533 | 22467 | 79241 | 20759 | 80919 | 19081 | 12 |
| 49 | 77562 | 22438 | 79269 | 20731 | 80947 | 19053 | 11 |
| 50 | 9.77591 | 10.22409 | 9.79297 | 10.20703 | 9.80975 | 10.19025 | 10 |
| 51 | 77619 | 22381 | 79326 | 20674 | 81003 | 18997 | 9 |
| 52 | 77648 | 22352 | 79354 | 20646 | 81030 | 18970 | 8 |
| 53 | 77677 | 22323 | 79382 | 20618 | 81058 | 18942 | 7 |
| 54 | 77706 | 22294 | 79410 | 20590 | 81086 | 18914 | 6 |
| 55 | 77734 | 22266 | 79438 | 20562 | 81113 | 18887 | 5 |
| 56 | 77763 | 22237 | 79466 | 20534 | 81141 | 18859 | 4 |
| 57 | 77791 | 22209 | 79495 | 20505 | 81169 | 18831 | 3 |
| 58 | 77820 | 22180 | 79523 | 20477 | 81196 | 18804 | 2 |
| 59 | 77849 | 22151 | 79551 | 20449 | 81224 | 18776 | 1 |
| 60 | 77877 | 22123 | 79579 | 20421 | 81252 | 18748 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 59° | | 58° | | 57° | | |

| ′ | 33° | | 34° | | 35° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.81252 | 10.18748 | 9.82899 | 10.17101 | 9.84523 | 10.15477 | 60 |
| 1 | 81279 | 18721 | 82926 | 17074 | 84550 | 15450 | 59 |
| 2 | 81307 | 18693 | 82953 | 17047 | 84576 | 15424 | 58 |
| 3 | 81335 | 18665 | 82980 | 17020 | 84603 | 15397 | 57 |
| 4 | 81362 | 18638 | 83008 | 16992 | 84630 | 15370 | 56 |
| 5 | 81390 | 18610 | 83035 | 16965 | 84657 | 15343 | 55 |
| 6 | 81418 | 18582 | 83062 | 16938 | 84684 | 15316 | 54 |
| 7 | 81445 | 18555 | 83089 | 16911 | 84711 | 15289 | 53 |
| 8 | 81473 | 18527 | 83117 | 16883 | 84738 | 15262 | 52 |
| 9 | 81500 | 18500 | 83144 | 16856 | 84764 | 15236 | 51 |
| 10 | 9.81528 | 10.18472 | 9.83171 | 10.16829 | 9.84791 | 10.15209 | 50 |
| 11 | 81556 | 18444 | 83198 | 16802 | 84818 | 15182 | 49 |
| 12 | 81583 | 18417 | 83225 | 16775 | 84845 | 15155 | 48 |
| 13 | 81611 | 18389 | 83252 | 16748 | 84872 | 15128 | 47 |
| 14 | 81638 | 18362 | 83280 | 16720 | 84899 | 15101 | 46 |
| 15 | 81666 | 18334 | 83307 | 16693 | 84925 | 15075 | 45 |
| 16 | 81693 | 18307 | 83334 | 16666 | 84952 | 15048 | 44 |
| 17 | 81721 | 18279 | 83361 | 16639 | 84979 | 15021 | 43 |
| 18 | 81748 | 18252 | 83388 | 16612 | 85006 | 14994 | 42 |
| 19 | 81776 | 18224 | 83415 | 16585 | 85033 | 14967 | 41 |
| 20 | 9.81803 | 10.18197 | 9.83442 | 10.16558 | 9.85059 | 10.14941 | 40 |
| 21 | 81831 | 18169 | 83470 | 16530 | 85086 | 14914 | 39 |
| 22 | 81858 | 18142 | 83497 | 16503 | 85113 | 14887 | 38 |
| 23 | 81886 | 18114 | 83524 | 16476 | 85140 | 14860 | 37 |
| 24 | 81913 | 18087 | 83551 | 16449 | 85166 | 14834 | 36 |
| 25 | 81941 | 18059 | 83578 | 16422 | 85193 | 14807 | 35 |
| 26 | 81968 | 18032 | 83605 | 16395 | 85220 | 14780 | 34 |
| 27 | 81996 | 18004 | 83632 | 16368 | 85247 | 14753 | 33 |
| 28 | 82023 | 17977 | 83659 | 16341 | 85273 | 14727 | 32 |
| 29 | 82051 | 17949 | 83686 | 16314 | 85300 | 14700 | 31 |
| 30 | 9.82078 | 10.17922 | 9.83713 | 10.16287 | 9.85327 | 10.14673 | 30 |
| 31 | 82106 | 17894 | 83740 | 16260 | 85354 | 14646 | 29 |
| 32 | 82133 | 17867 | 83768 | 16232 | 85380 | 14620 | 28 |
| 33 | 82161 | 17839 | 83795 | 16205 | 85407 | 14593 | 27 |
| 34 | 82188 | 17812 | 83822 | 16178 | 85434 | 14566 | 26 |
| 35 | 82215 | 17785 | 83849 | 16151 | 85460 | 14540 | 25 |
| 36 | 82243 | 17757 | 83876 | 16124 | 85487 | 14513 | 24 |
| 37 | 82270 | 17730 | 83903 | 16097 | 85514 | 14486 | 23 |
| 38 | 82298 | 17702 | 83930 | 16070 | 85540 | 14460 | 22 |
| 39 | 82325 | 17675 | 83957 | 16043 | 85567 | 14433 | 21 |
| 40 | 9.82352 | 10.17648 | 9.83984 | 10.16016 | 9.85594 | 10.14406 | 20 |
| 41 | 82380 | 17620 | 84011 | 15989 | 85620 | 14380 | 19 |
| 42 | 82407 | 17593 | 84038 | 15962 | 85647 | 14353 | 18 |
| 43 | 82435 | 17565 | 84065 | 15935 | 85674 | 14326 | 17 |
| 44 | 82462 | 17538 | 84092 | 15908 | 85700 | 14300 | 16 |
| 45 | 82489 | 17511 | 84119 | 15881 | 85727 | 14273 | 15 |
| 46 | 82517 | 17483 | 84146 | 15854 | 85754 | 14246 | 14 |
| 47 | 82544 | 17456 | 84173 | 15827 | 85780 | 14220 | 13 |
| 48 | 82571 | 17429 | 84200 | 15800 | 85807 | 14193 | 12 |
| 49 | 82599 | 17401 | 84227 | 15773 | 85834 | 14166 | 11 |
| 50 | 9.82626 | 10.17374 | 9.84254 | 10.15746 | 9.85860 | 10.14140 | 10 |
| 51 | 82653 | 17347 | 84280 | 15720 | 85887 | 14113 | 9 |
| 52 | 82681 | 17319 | 84307 | 15693 | 85913 | 14087 | 8 |
| 53 | 82708 | 17292 | 84334 | 15666 | 85940 | 14060 | 7 |
| 54 | 82735 | 17265 | 84361 | 15639 | 85967 | 14033 | 6 |
| 55 | 82762 | 17238 | 84388 | 15612 | 85993 | 14007 | 5 |
| 56 | 82790 | 17210 | 84415 | 15585 | 86020 | 13980 | 4 |
| 57 | 82817 | 17183 | 84442 | 15558 | 86046 | 13954 | 3 |
| 58 | 82844 | 17156 | 84469 | 15531 | 86073 | 13927 | 2 |
| 59 | 82871 | 17129 | 84496 | 15504 | 86100 | 13900 | 1 |
| 60 | 82899 | 17101 | 84523 | 15477 | 86126 | 13874 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 56° | | 55° | | 54° | | |

| ′ | 36° | | 37° | | 38° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.86126 | 10.13874 | 9.87711 | 10.12289 | 9.89281 | 10.10719 | 60 |
| 1 | 86153 | 13847 | 87738 | 12262 | 89307 | 10693 | 59 |
| 2 | 86179 | 13821 | 87764 | 12236 | 89333 | 10667 | 58 |
| 3 | 86206 | 13794 | 87790 | 12210 | 89359 | 10641 | 57 |
| 4 | 86232 | 13768 | 87817 | 12183 | 89385 | 10615 | 56 |
| 5 | 86259 | 13741 | 87843 | 12157 | 89411 | 10589 | 55 |
| 6 | 86285 | 13715 | 87869 | 12131 | 89437 | 10563 | 54 |
| 7 | 86312 | 13688 | 87895 | 12105 | 89463 | 10537 | 53 |
| 8 | 86338 | 13662 | 87922 | 12078 | 89489 | 10511 | 52 |
| 9 | 86365 | 13635 | 87948 | 12052 | 89515 | 10485 | 51 |
| 10 | 9.86392 | 10.13608 | 9.87974 | 10.12026 | 9.89541 | 10.10459 | 50 |
| 11 | 86418 | 13582 | 88000 | 12000 | 89567 | 10433 | 49 |
| 12 | 86445 | 13555 | 88027 | 11973 | 89593 | 10407 | 48 |
| 13 | 86471 | 13529 | 88053 | 11947 | 89619 | 10381 | 47 |
| 14 | 86498 | 13502 | 88079 | 11921 | 89645 | 10355 | 46 |
| 15 | 86524 | 13476 | 88105 | 11895 | 89671 | 10329 | 45 |
| 16 | 86551 | 13449 | 88131 | 11869 | 89697 | 10303 | 44 |
| 17 | 86577 | 13423 | 88158 | 11842 | 89723 | 10277 | 43 |
| 18 | 86603 | 13397 | 88184 | 11816 | 89749 | 10251 | 42 |
| 19 | 86630 | 13370 | 88210 | 11790 | 89775 | 10225 | 41 |
| 20 | 9.86656 | 10.13344 | 9.88236 | 10.11764 | 9.89801 | 10.10199 | 40 |
| 21 | 86683 | 13317 | 88262 | 11738 | 89827 | 10173 | 39 |
| 22 | 86709 | 13291 | 88289 | 11711 | 89853 | 10147 | 38 |
| 23 | 86736 | 13264 | 88315 | 11685 | 89879 | 10121 | 37 |
| 24 | 86762 | 13238 | 88341 | 11659 | 89905 | 10095 | 36 |
| 25 | 86789 | 13211 | 88367 | 11633 | 89931 | 10069 | 35 |
| 26 | 86815 | 13185 | 88393 | 11607 | 89957 | 10043 | 34 |
| 27 | 86842 | 13158 | 88420 | 11580 | 89983 | 10017 | 33 |
| 28 | 86868 | 13132 | 88446 | 11554 | 90009 | 09991 | 32 |
| 29 | 86894 | 13106 | 88472 | 11528 | 90035 | 09965 | 31 |
| 30 | 9.86921 | 10.13079 | 9.88498 | 10.11502 | 9.90061 | 10.09939 | 30 |
| 31 | 86947 | 13053 | 88524 | 11476 | 90086 | 09914 | 29 |
| 32 | 86974 | 13026 | 88550 | 11450 | 90112 | 09888 | 28 |
| 33 | 87000 | 13000 | 88577 | 11423 | 90138 | 09862 | 27 |
| 34 | 87027 | 12973 | 88603 | 11397 | 90164 | 09836 | 26 |
| 35 | 87053 | 12947 | 88629 | 11371 | 90190 | 09810 | 25 |
| 36 | 87079 | 12921 | 88655 | 11345 | 90216 | 09784 | 24 |
| 37 | 87106 | 12894 | 88681 | 11319 | 90242 | 09758 | 23 |
| 38 | 87132 | 12868 | 88707 | 11293 | 90268 | 09732 | 22 |
| 39 | 87158 | 12842 | 88733 | 11267 | 90294 | 09706 | 21 |
| 40 | 9.87185 | 10.12815 | 9.88759 | 10.11241 | 9.90320 | 10.09680 | 20 |
| 41 | 87211 | 12789 | 88786 | 11214 | 90346 | 09654 | 19 |
| 42 | 87238 | 12762 | 88812 | 11188 | 90371 | 09629 | 18 |
| 43 | 87264 | 12736 | 88838 | 11162 | 90397 | 09603 | 17 |
| 44 | 87290 | 12710 | 88864 | 11136 | 90423 | 09577 | 16 |
| 45 | 87317 | 12683 | 88890 | 11110 | 90449 | 09551 | 15 |
| 46 | 87343 | 12657 | 88916 | 11084 | 90475 | 09525 | 14 |
| 47 | 87369 | 12631 | 88942 | 11058 | 90501 | 09499 | 13 |
| 48 | 87396 | 12604 | 88968 | 11032 | 90527 | 09473 | 12 |
| 49 | 87422 | 12578 | 88994 | 11006 | 90553 | 09447 | 11 |
| 50 | 9.87448 | 10.12552 | 9.89020 | 10.10980 | 9.90578 | 10.09422 | 10 |
| 51 | 87475 | 12525 | 89046 | 10954 | 90604 | 09396 | 9 |
| 52 | 87501 | 12499 | 89073 | 10927 | 90630 | 09370 | 8 |
| 53 | 87527 | 12473 | 89099 | 10901 | 90656 | 09344 | 7 |
| 54 | 87554 | 12446 | 89125 | 10875 | 90682 | 09318 | 6 |
| 55 | 87580 | 12420 | 89151 | 10849 | 90708 | 09292 | 5 |
| 56 | 87606 | 12394 | 89177 | 10823 | 90734 | 09266 | 4 |
| 57 | 87633 | 12367 | 89203 | 10797 | 90759 | 09241 | 3 |
| 58 | 87659 | 12341 | 89229 | 10771 | 90785 | 09215 | 2 |
| 59 | 87685 | 12315 | 89255 | 10745 | 90811 | 09189 | 1 |
| 60 | 87711 | 12289 | 89281 | 10719 | 90837 | 09163 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 53° | | 52° | | 51° | | |

| ′ | 39° | | 40° | | 41° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.90837 | 10.09163 | 9.92381 | 10.07619 | 9.93916 | 10.06084 | 60 |
| 1 | 90863 | 09137 | 92407 | 07593 | 93942 | 06058 | 59 |
| 2 | 90889 | 09111 | 92433 | 07567 | 93967 | 06033 | 58 |
| 3 | 90914 | 09086 | 92458 | 07542 | 93993 | 06007 | 57 |
| 4 | 90940 | 09060 | 92484 | 07516 | 94018 | 05982 | 56 |
| 5 | 90966 | 09034 | 92510 | 07490 | 94044 | 05956 | 55 |
| 6 | 90992 | 09008 | 92535 | 07465 | 94069 | 05931 | 54 |
| 7 | 91018 | 08982 | 92561 | 07439 | 94095 | 05905 | 53 |
| 8 | 91043 | 08957 | 92587 | 07413 | 94120 | 05880 | 52 |
| 9 | 91069 | 08931 | 92612 | 07388 | 94146 | 05854 | 51 |
| 10 | 9.91095 | 10.08905 | 9.92638 | 10.07362 | 9.94171 | 10.05829 | 50 |
| 11 | 91121 | 08879 | 92663 | 07337 | 94197 | 05803 | 49 |
| 12 | 91147 | 08853 | 92689 | 07311 | 94222 | 05778 | 48 |
| 13 | 91172 | 08828 | 92715 | 07285 | 94248 | 05752 | 47 |
| 14 | 91198 | 08802 | 92740 | 07260 | 94273 | 05727 | 46 |
| 15 | 91224 | 08776 | 92766 | 07234 | 94299 | 05701 | 45 |
| 16 | 91250 | 08750 | 92792 | 07208 | 94324 | 05676 | 44 |
| 17 | 91276 | 08724 | 92817 | 07183 | 94350 | 05650 | 43 |
| 18 | 91301 | 08699 | 92843 | 07157 | 94375 | 05625 | 42 |
| 19 | 91327 | 08673 | 92868 | 07132 | 94401 | 05599 | 41 |
| 20 | 9.91353 | 10.08647 | 9.92894 | 10.07106 | 9.94426 | 10.05574 | 40 |
| 21 | 91379 | 08621 | 92920 | 07080 | 94452 | 05548 | 39 |
| 22 | 91404 | 08596 | 92945 | 07055 | 94477 | 05523 | 38 |
| 23 | 91430 | 08570 | 92971 | 07029 | 94503 | 05497 | 37 |
| 24 | 91456 | 08544 | 92996 | 07004 | 94528 | 05472 | 36 |
| 25 | 91482 | 08518 | 93022 | 06978 | 94554 | 05446 | 35 |
| 26 | 91507 | 08493 | 93048 | 06952 | 94579 | 05421 | 34 |
| 27 | 91533 | 08467 | 93073 | 06927 | 94604 | 05396 | 33 |
| 28 | 91559 | 08441 | 93099 | 06901 | 94630 | 05370 | 32 |
| 29 | 91585 | 08415 | 93124 | 06876 | 94655 | 05345 | 31 |
| 30 | 9.91610 | 10.08390 | 9.93150 | 10.06850 | 9.94681 | 10.05319 | 30 |
| 31 | 91636 | 08364 | 93175 | 06825 | 94706 | 05294 | 29 |
| 32 | 91662 | 08338 | 93201 | 06799 | 94732 | 05268 | 28 |
| 33 | 91688 | 08312 | 93227 | 06773 | 94757 | 05243 | 27 |
| 34 | 91713 | 08287 | 93252 | 06748 | 94783 | 05217 | 26 |
| 35 | 91739 | 08261 | 93278 | 06722 | 94808 | 05192 | 25 |
| 36 | 91765 | 08235 | 93303 | 06697 | 94834 | 05166 | 24 |
| 37 | 91791 | 08209 | 93329 | 06671 | 94859 | 05141 | 23 |
| 38 | 91816 | 08184 | 93354 | 06646 | 94884 | 05116 | 22 |
| 39 | 91842 | 08158 | 93380 | 06620 | 94910 | 05090 | 21 |
| 40 | 9.91868 | 10.08132 | 9.93406 | 10.06594 | 9.94935 | 10.05065 | 20 |
| 41 | 91893 | 08107 | 93431 | 06569 | 94961 | 05039 | 19 |
| 42 | 91919 | 08081 | 93457 | 06543 | 94986 | 05014 | 18 |
| 43 | 91945 | 08055 | 93482 | 06518 | 95012 | 04988 | 17 |
| 44 | 91971 | 08029 | 93508 | 06492 | 95037 | 04963 | 16 |
| 45 | 91996 | 08004 | 93533 | 06467 | 95062 | 04938 | 15 |
| 46 | 92022 | 07978 | 93559 | 06441 | 95088 | 04912 | 14 |
| 47 | 92048 | 07952 | 93584 | 06416 | 95113 | 04887 | 13 |
| 48 | 92073 | 07927 | 93610 | 06390 | 95139 | 04861 | 12 |
| 49 | 92099 | 07901 | 93636 | 06364 | 95164 | 04836 | 11 |
| 50 | 9.92125 | 10.07875 | 9.93661 | 10.06339 | 9.95190 | 10.04810 | 10 |
| 51 | 92150 | 07850 | 93687 | 06313 | 95215 | 04785 | 9 |
| 52 | 92176 | 07824 | 93712 | 06288 | 95240 | 04760 | 8 |
| 53 | 92202 | 07798 | 93738 | 06262 | 95266 | 04734 | 7 |
| 54 | 92227 | 07773 | 93763 | 06237 | 95291 | 04709 | 6 |
| 55 | 92253 | 07747 | 93789 | 06211 | 95317 | 04683 | 5 |
| 56 | 92279 | 07721 | 93814 | 06186 | 95342 | 04658 | 4 |
| 57 | 92304 | 07696 | 93840 | 06160 | 95368 | 04632 | 3 |
| 58 | 92330 | 07670 | 93865 | 06135 | 95393 | 04607 | 2 |
| 59 | 92356 | 07644 | 93891 | 06109 | 95418 | 04582 | 1 |
| 60 | 92381 | 07619 | 93916 | 06084 | 95444 | 04556 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 50° | | 49° | | 48° | | |

| ′ | 42° | | 43° | | 44° | | ′ |
|---|---|---|---|---|---|---|---|
| | Tan | Cotan | Tan | Cotan | Tan | Cotan | |
| 0 | 9.95444 | 10.04556 | 9.96966 | 10.03034 | 9.98484 | 10.01516 | 60 |
| 1 | 95469 | 04531 | 96991 | 03009 | 98509 | 01491 | 59 |
| 2 | 95495 | 04505 | 97016 | 02984 | 98534 | 01466 | 58 |
| 3 | 95520 | 04480 | 97042 | 02958 | 98560 | 01440 | 57 |
| 4 | 95545 | 04455 | 97067 | 02933 | 98585 | 01415 | 56 |
| 5 | 95571 | 04429 | 97092 | 02908 | 98610 | 01390 | 55 |
| 6 | 95596 | 04404 | 97118 | 02882 | 98635 | 01365 | 54 |
| 7 | 95622 | 04378 | 97143 | 02857 | 98661 | 01339 | 53 |
| 8 | 95647 | 04353 | 97168 | 02832 | 98686 | 01314 | 52 |
| 9 | 95672 | 04328 | 97193 | 02807 | 98711 | 01289 | 51 |
| 10 | 9.95698 | 10.04302 | 9.97219 | 10.02781 | 9.98737 | 10.01263 | 50 |
| 11 | 95723 | 04277 | 97244 | 02756 | 98762 | 01238 | 49 |
| 12 | 95748 | 04252 | 97269 | 02731 | 98787 | 01213 | 48 |
| 13 | 95774 | 04226 | 97295 | 02705 | 98812 | 01188 | 47 |
| 14 | 95799 | 04201 | 97320 | 02680 | 98838 | 01162 | 46 |
| 15 | 95825 | 04175 | 97345 | 02655 | 98863 | 01137 | 45 |
| 16 | 95850 | 04150 | 97371 | 02629 | 98888 | 01112 | 44 |
| 17 | 95875 | 04125 | 97396 | 02604 | 98913 | 01087 | 43 |
| 18 | 95901 | 04099 | 97421 | 02579 | 98939 | 01061 | 42 |
| 19 | 95926 | 04074 | 97447 | 02553 | 98964 | 01036 | 41 |
| 20 | 9.95952 | 10.04048 | 9.97472 | 10.02528 | 9.98989 | 10.01011 | 40 |
| 21 | 95977 | 04023 | 97497 | 02503 | 99015 | 00985 | 39 |
| 22 | 96002 | 03998 | 97523 | 02477 | 99040 | 00960 | 38 |
| 23 | 96028 | 03972 | 97548 | 02452 | 99065 | 00935 | 37 |
| 24 | 96053 | 03947 | 97573 | 02427 | 99090 | 00910 | 36 |
| 25 | 96078 | 03922 | 97598 | 02402 | 99116 | 00884 | 35 |
| 26 | 96104 | 03896 | 97624 | 02376 | 99141 | 00859 | 34 |
| 27 | 96129 | 03871 | 97649 | 02351 | 99166 | 00834 | 33 |
| 28 | 96155 | 03845 | 97674 | 02326 | 99191 | 00809 | 32 |
| 29 | 96180 | 03820 | 97700 | 02300 | 99217 | 00783 | 31 |
| 30 | 9.96205 | 10.03795 | 9.97725 | 10.02275 | 9.99242 | 10.00758 | 30 |
| 31 | 96231 | 03769 | 97750 | 02250 | 99267 | 00733 | 29 |
| 32 | 96256 | 03744 | 97776 | 02224 | 99293 | 00707 | 28 |
| 33 | 96281 | 03719 | 97801 | 02199 | 99318 | 00682 | 27 |
| 34 | 96307 | 03693 | 97826 | 02174 | 99343 | 00657 | 26 |
| 35 | 96332 | 03668 | 97851 | 02149 | 99368 | 00632 | 25 |
| 36 | 96357 | 03643 | 97877 | 02123 | 99394 | 00606 | 24 |
| 37 | 96383 | 03617 | 97902 | 02098 | 99419 | 00581 | 23 |
| 38 | 96408 | 03592 | 97927 | 02073 | 99444 | 00556 | 22 |
| 39 | 96433 | 03567 | 97953 | 02047 | 99469 | 00531 | 21 |
| 40 | 9.96459 | 10.03541 | 9.97978 | 10.02022 | 9.99495 | 10.00505 | 20 |
| 41 | 96484 | 03516 | 98003 | 01997 | 99520 | 00480 | 19 |
| 42 | 96510 | 03490 | 98029 | 01971 | 99545 | 00455 | 18 |
| 43 | 96535 | 03465 | 98054 | 01946 | 99570 | 00430 | 17 |
| 44 | 96560 | 03440 | 98079 | 01921 | 99596 | 00404 | 16 |
| 45 | 96586 | 03414 | 98104 | 01896 | 99621 | 00379 | 15 |
| 46 | 96611 | 03389 | 98130 | 01870 | 99646 | 00354 | 14 |
| 47 | 96636 | 03364 | 98155 | 01845 | 99672 | 00328 | 13 |
| 48 | 96662 | 03338 | 98180 | 01820 | 99697 | 00303 | 12 |
| 49 | 96687 | 03313 | 98206 | 01794 | 99722 | 00278 | 11 |
| 50 | 9.96712 | 10.03288 | 9.98231 | 10.01769 | 9.99747 | 10.00253 | 10 |
| 51 | 96738 | 03262 | 98256 | 01744 | 99773 | 00227 | 9 |
| 52 | 96763 | 03237 | 98281 | 01719 | 99798 | 00202 | 8 |
| 53 | 96788 | 03212 | 98307 | 01693 | 99823 | 00177 | 7 |
| 54 | 96814 | 03186 | 98332 | 01668 | 99848 | 00152 | 6 |
| 55 | 96839 | 03161 | 98357 | 01643 | 99874 | 00126 | 5 |
| 56 | 96864 | 03136 | 98383 | 01617 | 99899 | 00101 | 4 |
| 57 | 96890 | 03110 | 98408 | 01592 | 99924 | 00076 | 3 |
| 58 | 96915 | 03085 | 98433 | 01567 | 99949 | 00051 | 2 |
| 59 | 96940 | 03060 | 98458 | 01542 | 99975 | 00025 | 1 |
| 60 | 96966 | 03034 | 98484 | 01516 | 10.00000 | 00000 | 0 |
| ′ | Cotan | Tan | Cotan | Tan | Cotan | Tan | ′ |
| | 47° | | 46° | | 45° | | |

## TABLE IX.—FUNCTIONS OF A ONE-DEGREE CURVE.

The Long Chords, Mid-Ordinates, Externals, and Tangent Distances of this table are for a curve of 5730 feet radius. To find the corresponding functions of any other curve divide the tabular values by the degree of curve.

For metric curves having 20-metre chords, multiply tne degree by 5 and enter the table with the result as a value of $D$, the tabular values being taken as metres instead of feet

Thus for a 1° 30′ metric curve having $I = 45°$ the tangent distance is $T = \frac{2373.4}{1.5 \times 5} = 316.45$ metres. Again, suppose $I = 38°$ and the long chord = 373.1 m. known and $D$ required. The tabular $L. C.$ is 3731 m.; therefore $D = \frac{3731.0}{373.1 \times 5} = 2° 0'$.

|  | 0° |  |  |  | 1° |  |  |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | L. C. | M. | E. | T. | L. C. | M. | E. | T. |  |
| 0 | 0.00 | 0.000 | 0.000 | 0.00 | 100.00 | 0.218 | 0.218 | 50.00 | 0 |
| 2 | 3.33 | 0.000 | 0.000 | 1.67 | 103.33 | 0.233 | 0.233 | 51.67 | 2 |
| 4 | 6.67 | 0.001 | 0.001 | 3.33 | 106.66 | 0.248 | 0.248 | 53.33 | 4 |
| 6 | 10.00 | 0.002 | 0.002 | 5.00 | 110.00 | 0.264 | 0.264 | 55.00 | 6 |
| 8 | 13.33 | 0.004 | 0.004 | 6.67 | 113.33 | 0.280 | 0.280 | 56.67 | 8 |
| 10 | 16.67 | 0.006 | 0.006 | 8.33 | 116.66 | 0.297 | 0.297 | 58.33 | 10 |
| 12 | 20.00 | 0.009 | 0.009 | 10.00 | 120 00 | 0.314 | 0.314 | 60.00 | 12 |
| 14 | 23.33 | 0.012 | 0.012 | 11.67 | 123.33 | 0.332 | 0.332 | 61.67 | 14 |
| 16 | 26.67 | 0.015 | 0.015 | 13.33 | 126.66 | 0.350 | 0.350 | 63.33 | 16 |
| 18 | 30.00 | 0.019 | 0.019 | 15.00 | 130.00 | 0.368 | 0.368 | 65.00 | 18 |
| 20 | 33.33 | 0.024 | 0.024 | 16.67 | 133.33 | 0.388 | 0.388 | 66.67 | 20 |
| 22 | 36.67 | 0.028 | 0.029 | 18.33 | 136.66 | 0.407 | 0.407 | 68.33 | 22 |
| 24 | 40.00 | 0.035 | 0.035 | 20.00 | 140.00 | 0.427 | 0.427 | 70.00 | 24 |
| 26 | 43.33 | 0.041 | 0.041 | 21.67 | 143.33 | 0.448 | 0.448 | 71.67 | 26 |
| 28 | 46.67 | 0.048 | 0.048 | 23.33 | 146.66 | 0.469 | 0.469 | 73.33 | 28 |
| 30 | 50.00 | 0.054 | 0.054 | 25.00 | 150.00 | 0.491 | 0.491 | 75.00 | 30 |
| 32 | 53 33 | 0 062 | 0.062 | 26.67 | 153.33 | 0.513 | 0.513 | 76.67 | 32 |
| 34 | 56.67 | 0 070 | 0.070 | 28.33 | 156.66 | 0.536 | 0.536 | 78.33 | 34 |
| 36 | 60.00 | 0.079 | 0.079 | 30.00 | 160.00 | 0.559 | 0.559 | 80.00 | 36 |
| 38 | 63.33 | 0.088 | 0.088 | 31.67 | 163.33 | 0.582 | 0.582 | 81.67 | 38 |
| 40 | 66.67 | 0.097 | 0.097 | 33.33 | 166.66 | 0.606 | 0.606 | 83.33 | 40 |
| 42 | 70.00 | 0.107 | 0.107 | 35.00 | 170.00 | 0.630 | 0.630 | 85.00 | 42 |
| 44 | 73.33 | 0.117 | 0.117 | 36.67 | 173 33 | 0.655 | 0.655 | 86.67 | 44 |
| 46 | 76.67 | 0.128 | 0.128 | 38.33 | 176.66 | 0.681 | 0.681 | 88.33 | 46 |
| 48 | 80.00 | 0.140 | 0.140 | 40.00 | 180.00 | 0.706 | 0.706 | 90.00 | 48 |
| 50 | 83.33 | 0.151 | 0.151 | 41.67 | 183 33 | 0 738 | 0.733 | 91.67 | 50 |
| 52 | 86.67 | 0.164 | 0.164 | 43.33 | 186.66 | 0.760 | 0.760 | 93.33 | 52 |
| 54 | 90 00 | 0 176 | 0.176 | 45 00 | 190.00 | 0.788 | 0.788 | 95.00 | 54 |
| 56 | 93 33 | 0.190 | 0.190 | 46.67 | 193.33 | 0.815 | 0.815 | 96.67 | 56 |
| 58 | 96.67 | 0.204 | 0.204 | 48 33 | 196.66 | 0.844 | 0.844 | 98.33 | 58 |
| 60 | 100.00 | 0.218 | 0.218 | 50 00 | 199.98 | 0 873 | 0 878 | 100.00 | 60 |

| ′ | 2° | | | | 3° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 199.98 | 0.873 | 0.873 | 100.00 | 299.96 | 1.964 | 1.964 | 150.07 | 0 |
| 2 | 203.31 | 0.902 | 0.902 | 101.67 | 303.29 | 2.008 | 2.009 | 151.74 | 2 |
| 4 | 206.64 | 0.932 | 0.932 | 103.34 | 306.62 | 2.053 | 2.054 | 153.41 | 4 |
| 6 | 209.97 | 0.962 | 0.962 | 105.01 | 309.95 | 2.098 | 2.099 | 155.08 | 6 |
| 8 | 213.31 | 0.993 | 0.993 | 106.68 | 313.29 | 2.143 | 2.144 | 156.75 | 8 |
| 10 | 216.64 | 1.024 | 1.024 | 108.35 | 316.62 | 2.188 | 2.189 | 158.42 | 10 |
| 12 | 219.97 | 1.056 | 1.056 | 110.02 | 319.95 | 2.235 | 2.236 | 160.09 | 12 |
| 14 | 223.30 | 1.088 | 1.088 | 111.69 | 323.28 | 2.282 | 2.283 | 161.76 | 14 |
| 16 | 226.64 | 1.121 | 1.121 | 113.36 | 326.62 | 2.329 | 2.330 | 163.43 | 16 |
| 18 | 229.97 | 1.154 | 1.154 | 115.02 | 329.95 | 2.376 | 2.377 | 165.09 | 18 |
| 20 | 233.30 | 1.188 | 1.188 | 116.69 | 333.28 | 2.424 | 2.425 | 166.76 | 20 |
| 22 | 236.63 | 1.222 | 1.222 | 118.36 | 336.61 | 2.473 | 2.474 | 168.43 | 22 |
| 24 | 239.97 | 1.256 | 1.256 | 120.03 | 339.95 | 2.523 | 2.523 | 170.10 | 24 |
| 26 | 243.30 | 1.292 | 1.292 | 121.70 | 343.28 | 2.572 | 2.573 | 171.77 | 26 |
| 28 | 246.63 | 1.328 | 1.328 | 123.37 | 346.61 | 2.622 | 2.623 | 173.44 | 28 |
| 30 | 249.96 | 1.364 | 1.364 | 125.03 | 349.94 | 2.672 | 2.673 | 175.10 | 30 |
| 32 | 253.29 | 1.399 | 1.399 | 126.70 | 353.27 | 2.724 | 2.725 | 176.72 | 32 |
| 34 | 256.62 | 1.437 | 1.437 | 128.37 | 356.60 | 2.776 | 2.777 | 178.39 | 34 |
| 36 | 259.96 | 1.475 | 1.475 | 130.04 | 359.94 | 2.828 | 2.829 | 180.06 | 36 |
| 38 | 263.29 | 1.513 | 1.513 | 131.71 | 363.27 | 2.880 | 2.881 | 181.73 | 38 |
| 40 | 266.62 | 1.552 | 1.552 | 133.38 | 366.60 | 2.933 | 2.934 | 183.40 | 40 |
| 42 | 269.96 | 1.592 | 1.592 | 135.05 | 369.94 | 2.987 | 2.988 | 185.07 | 42 |
| 44 | 273.29 | 1.632 | 1.632 | 136.72 | 373.27 | 3.042 | 3.043 | 186.74 | 44 |
| 46 | 276.62 | 1.672 | 1.672 | 138.38 | 376.60 | 3.096 | 3.097 | 188.40 | 46 |
| 43 | 279.96 | 1.712 | 1.712 | 140.05 | 379.94 | 3.151 | 3.152 | 190.07 | 48 |
| 50 | 283.29 | 1.752 | 1.752 | 141.72 | 383.27 | 3.206 | 3.207 | 191.74 | 50 |
| 52 | 286.62 | 1.794 | 1.794 | 143.39 | 386.60 | 3.263 | 3.264 | 193.41 | 52 |
| 54 | 289.96 | 1.836 | 1.836 | 145.06 | 389.94 | 3.320 | 3.321 | 195.08 | 54 |
| 56 | 293.29 | 1.878 | 1.878 | 146.73 | 393.27 | 3.377 | 3.378 | 196.75 | 56 |
| 58 | 296.62 | 1.921 | 1.921 | 148.40 | 396.60 | 3.434 | 3.435 | 198.42 | 58 |
| 60 | 299.96 | 1.964 | 1.964 | 150.07 | 399.94 | 3.491 | 3.492 | 200.09 | 60 |

| ′ | 4° | | | | 5° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 399.94 | 3.491 | 3.492 | 200.09 | 499.88 | 5.454 | 5.459 | 250.17 | 0 |
| 2 | 403.27 | 3.550 | 3.551 | 201.76 | 503.21 | 5.527 | 5.533 | 251.84 | 2 |
| 4 | 406.60 | 3.609 | 3.610 | 203.43 | 506.54 | 5.601 | 5.607 | 253.51 | 4 |
| 6 | 409.93 | 3.668 | 3.670 | 205.10 | 509.87 | 5.675 | 5.681 | 255.18 | 6 |
| 8 | 413.26 | 3.727 | 3.730 | 206.77 | 513.20 | 5.749 | 5.755 | 256.85 | 8 |
| 10 | 416.59 | 3.787 | 3.790 | 208.44 | 516.53 | 5.823 | 5.829 | 258.52 | 10 |
| 12 | 419.92 | 3.848 | 3.851 | 210.11 | 519.86 | 5.899 | 5.905 | 260.20 | 12 |
| 14 | 423.26 | 3.910 | 3.913 | 211.77 | 523.19 | 5.975 | 5.981 | 261.86 | 14 |
| 16 | 426.59 | 3.972 | 3.975 | 213.45 | 526.52 | 6.052 | 6.058 | 263.54 | 16 |
| 18 | 429.92 | 4.034 | 4.037 | 215.11 | 529.85 | 6.129 | 6.135 | 265.20 | 18 |
| 20 | 433.25 | 4.096 | 4.099 | 216.78 | 533.18 | 6.206 | 6.212 | 266.87 | 20 |
| 22 | 436.58 | 4.160 | 4.163 | 218.45 | 536.51 | 6.284 | 6.290 | 268.54 | 22 |
| 24 | 439.91 | 4.224 | 4.227 | 220.12 | 539.84 | 6.362 | 6.369 | 270.21 | 24 |
| 26 | 443.24 | 4.288 | 4.291 | 221.79 | 543.17 | 6.441 | 6.448 | 271.88 | 26 |
| 28 | 446.58 | 4.353 | 4.356 | 223.46 | 546.50 | 6.520 | 6.527 | 273.54 | 28 |
| 30 | 449.91 | 4.418 | 4.421 | 225.13 | 549.83 | 6.599 | 6.606 | 275.21 | 30 |
| 32 | 453.24 | 4.484 | 4.487 | 226.80 | 553.17 | 6.680 | 6.687 | 276.88 | 32 |
| 34 | 456.57 | 4.550 | 4.554 | 228.47 | 556.50 | 6.761 | 6.768 | 278.55 | 34 |
| 36 | 459.90 | 4.617 | 4.621 | 230.14 | 559.83 | 6.842 | 6.849 | 280.23 | 36 |
| 38 | 463.23 | 4.684 | 4.688 | 231.81 | 563.16 | 6.923 | 6.931 | 281.90 | 38 |
| 40 | 466.56 | 4.751 | 4.755 | 233.48 | 566.49 | 7.005 | 7.013 | 283.57 | 40 |
| 42 | 469.89 | 4.820 | 4.824 | 235.15 | 569.82 | 7.088 | 7.096 | 285.24 | 42 |
| 44 | 478.23 | 4.889 | 4.893 | 236.82 | 573.15 | 7.171 | 7.180 | 286.91 | 44 |
| 46 | 476.56 | 4.958 | 4.962 | 238.48 | 576.48 | 7.255 | 7.264 | 288.59 | 46 |
| 48 | 479.89 | 5.027 | 5.031 | 240.15 | 579.81 | 7.339 | 7.348 | 290.26 | 48 |
| 50 | 483.22 | 5.096 | 5.100 | 241.82 | 583.14 | 7.423 | 7.432 | 291.93 | 50 |
| 52 | 486.55 | 5.167 | 5.171 | 243.49 | 586.47 | 7.508 | 7.517 | 293.60 | 52 |
| 54 | 489.88 | 5.238 | 5.243 | 245.16 | 589.80 | 7.593 | 7.603 | 295.27 | 54 |
| 56 | 493.21 | 5.310 | 5.315 | 216.83 | 593.13 | 7.678 | 7.689 | 296.95 | 56 |
| 58 | 496.54 | 5.382 | 5.387 | 248.50 | 596.46 | 7.764 | 7.775 | 298.62 | 58 |
| 60 | 499.88 | 5.454 | 5.459 | 250.17 | 599.80 | 7.850 | 7.861 | 300.30 | 60 |

| ′ | 6° | | | | 7° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 599.80 | 7.850 | 7.861 | 300.30 | 699.60 | 10.69 | 10.71 | 350.44 | 0 |
| 2 | 603.13 | 7.940 | 7.951 | 301.97 | 702.93 | 10.79 | 10.81 | 352.11 | 2 |
| 4 | 606.46 | 8.030 | 8.041 | 303.64 | 706.26 | 10.90 | 10.92 | 353.79 | 4 |
| 6 | 609.78 | 8.120 | 8.131 | 305.31 | 709.58 | 11.00 | 11.02 | 355.46 | 6 |
| 8 | 613.11 | 8.210 | 8.221 | 306.98 | 712.91 | 11.11 | 11.13 | 357.13 | 8 |
| 10 | 616.44 | 8.300 | 8.311 | 308.65 | 716.24 | 11.21 | 11.23 | 358.81 | 10 |
| 12 | 619.76 | 8.390 | 8.401 | 310.32 | 719.56 | 11.31 | 11.33 | 360.48 | 12 |
| 14 | 623.09 | 8.480 | 8.491 | 311.99 | 722.89 | 11.42 | 11.44 | 362.15 | 14 |
| 16 | 626.42 | 8.570 | 8.581 | 313.66 | 726.21 | 11.52 | 11.54 | 363.83 | 16 |
| 18 | 629.74 | 8.660 | 8.671 | 315.33 | 729.53 | 11.63 | 11.65 | 365.50 | 18 |
| 20 | 633.07 | 8.750 | 8.761 | 317.00 | 732.86 | 11.73 | 11.75 | 367.17 | 20 |
| 22 | 636.40 | 8.844 | 8.856 | 318.67 | 736.19 | 11.84 | 11.86 | 368.85 | 22 |
| 24 | 639.72 | 8.939 | 8.951 | 320.34 | 739.51 | 11.95 | 11.97 | 370.52 | 24 |
| 26 | 643.05 | 9.033 | 9.046 | 322.01 | 742.84 | 12.06 | 12.08 | 372.19 | 26 |
| 28 | 646.38 | 9.128 | 9.141 | 323.68 | 746.17 | 12.17 | 12.19 | 373.86 | 28 |
| 30 | 649.70 | 9.222 | 9.236 | 325.35 | 749.49 | 12.27 | 12.30 | 375.54 | 30 |
| 32 | 653.03 | 9.317 | 9.331 | 327.02 | 752.82 | 12.38 | 12.41 | 377.22 | 32 |
| 34 | 656.36 | 9.411 | 9.426 | 328.69 | 756.15 | 12.49 | 12.52 | 378.89 | 34 |
| 36 | 659.69 | 9.506 | 9.521 | 330.37 | 759.47 | 12.60 | 12.63 | 380.57 | 36 |
| 38 | 663.02 | 9.600 | 9.616 | 332.04 | 762.80 | 12.71 | 12.74 | 382.24 | 38 |
| 40 | 666.34 | 9.695 | 9.712 | 333.71 | 766.13 | 12.82 | 12.85 | 383.92 | 40 |
| 42 | 669.67 | 9.794 | 9.812 | 335.38 | 769.45 | 12.93 | 12.96 | 385.60 | 42 |
| 44 | 673.00 | 9.894 | 9.912 | 337.05 | 772.78 | 13.04 | 13.08 | 387.27 | 44 |
| 46 | 676.32 | 9.993 | 10.01 | 338.73 | 776.11 | 13.15 | 13.19 | 388.95 | 46 |
| 48 | 679.65 | 10.09 | 10.11 | 340.40 | 779.43 | 13.26 | 13.31 | 390.62 | 48 |
| 50 | 682.96 | 10.19 | 10.21 | 342.07 | 782.76 | 13.37 | 13.42 | 392.30 | 50 |
| 52 | 686.30 | 10.29 | 10.31 | 343.74 | 786.09 | 13.48 | 13.53 | 393.98 | 52 |
| 54 | 689.63 | 10.39 | 10.41 | 345.41 | 789.41 | 13.59 | 13.65 | 395.65 | 54 |
| 56 | 692.96 | 10.49 | 10.51 | 347.08 | 792.74 | 13.70 | 13.76 | 397.33 | 56 |
| 58 | 696.28 | 10.59 | 10.61 | 348.76 | 796.07 | 13.81 | 13.88 | 399.01 | 58 |
| 60 | 699.60 | 10.69 | 10.71 | 350.44 | 799.40 | 13.96 | 13.99 | 400.70 | 60 |

| ′ | 8° | | | | 9° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 799.40 | 13.96 | 13.99 | 400.70 | 899.10 | 17.66 | 17.71 | 450.95 | 0 |
| 2 | 802.72 | 14.07 | 14.10 | 402.37 | 902.42 | 17.79 | 17.84 | 452.63 | 2 |
| 4 | 806.04 | 14.19 | 14.22 | 404.05 | 905.74 | 17.92 | 17.98 | 454.31 | 4 |
| 6 | 809.37 | 14.31 | 14.34 | 405.72 | 909.07 | 18.06 | 18.11 | 455.98 | 6 |
| 8 | 812.69 | 14.43 | 14.46 | 407.39 | 912.39 | 18.19 | 18.25 | 457.66 | 8 |
| 10 | 816.01 | 14.55 | 14.58 | 409.06 | 915.71 | 18.32 | 18.38 | 459.34 | 10 |
| 12 | 819.34 | 14.66 | 14.70 | 410.74 | 919.04 | 18.46 | 18.52 | 461.02 | 12 |
| 14 | 822.66 | 14.78 | 14.82 | 412.41 | 922.36 | 18.59 | 18.65 | 462.70 | 14 |
| 16 | 825.98 | 14.90 | 14.94 | 414.08 | 925.68 | 18.72 | 18.79 | 464.37 | 16 |
| 18 | 829.31 | 15.02 | 15.06 | 415.75 | 929.01 | 18.86 | 18.92 | 466.05 | 18 |
| 20 | 832.63 | 15.14 | 15.18 | 417.43 | 932.33 | 18.99 | 19.06 | 467.73 | 20 |
| 22 | 835.95 | 15.26 | 15.30 | 419.10 | 935.65 | 19.12 | 19.19 | 469.41 | 22 |
| 24 | 839.28 | 15.38 | 15.43 | 420.77 | 938.98 | 19.26 | 19.33 | 471.08 | 24 |
| 26 | 842.60 | 15.51 | 15.55 | 422.45 | 942.30 | 19.40 | 19.47 | 472.76 | 26 |
| 28 | 845.92 | 15.63 | 15.68 | 424.12 | 945.62 | 19.54 | 19.61 | 474.43 | 28 |
| 30 | 849.25 | 15.75 | 15.80 | 425.79 | 948.95 | 19.68 | 19.75 | 476.10 | 30 |
| 32 | 852.57 | 15.88 | 15.93 | 427.47 | 952.27 | 19.82 | 19.89 | 477.78 | 32 |
| 34 | 855.89 | 16.00 | 16.05 | 429.15 | 955.59 | 19.96 | 20.03 | 479.46 | 34 |
| 36 | 859.22 | 16.12 | 16.18 | 430.82 | 958.92 | 20.10 | 20.17 | 481.14 | 36 |
| 38 | 862.54 | 16.25 | 16.30 | 432.50 | 962.24 | 20.24 | 20.31 | 482.83 | 38 |
| 40 | 865.86 | 16.38 | 16.43 | 434.18 | 965.56 | 20.38 | 20.45 | 484.51 | 40 |
| 42 | 869.19 | 16.50 | 16.55 | 435.86 | 968.89 | 20.52 | 20.59 | 486.19 | 42 |
| 44 | 872.51 | 16.63 | 16.68 | 437.54 | 972.21 | 20.66 | 20.74 | 487.87 | 44 |
| 46 | 875.83 | 16.76 | 16.81 | 439.21 | 975.53 | 20.80 | 20.88 | 489.56 | 46 |
| 48 | 879.16 | 16.89 | 16.94 | 440.89 | 978.86 | 20.94 | 21.03 | 491.24 | 48 |
| 50 | 882.48 | 17.02 | 17.07 | 442.57 | 982.18 | 21.09 | 21.17 | 492.92 | 50 |
| 52 | 885.80 | 17.14 | 17.19 | 444.25 | 985.50 | 21.23 | 21.31 | 494.60 | 52 |
| 54 | 889.13 | 17.27 | 17.32 | 445.93 | 988.83 | 21.37 | 21.46 | 496.28 | 54 |
| 56 | 892.45 | 17.40 | 17.45 | 447.60 | 992.15 | 21.51 | 21.60 | 497.96 | 56 |
| 58 | 895.77 | 17.53 | 17.58 | 449.28 | 995.47 | 21.65 | 21.75 | 499.65 | 58 |
| 60 | 899.10 | 17.66 | 17.71 | 450.95 | 998.80 | 21.80 | 21.89 | 501.32 | 60 |

| ′ | 10° | | | | 11° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 998.8 | 21.80 | 21.89 | 501.32 | 1098.4 | 26.38 | 26.50 | 551.74 | 0 |
| 2 | 1002.1 | 21.94 | 22.03 | 503.00 | 1101.7 | 26.54 | 26.66 | 553.42 | 2 |
| 4 | 1005.4 | 22.09 | 22.18 | 504.68 | 1105.0 | 26.70 | 26.83 | 555.10 | 4 |
| 6 | 1008.8 | 22.24 | 22.33 | 506.36 | 1108.3 | 26.86 | 26.99 | 556.78 | 6 |
| 8 | 1012.1 | 22.39 | 22.48 | 508.04 | 1111.7 | 27.02 | 27.16 | 558.46 | 8 |
| 10 | 1015.4 | 22.54 | 22.63 | 509.72 | 1115.0 | 27.19 | 27.32 | 560.14 | 10 |
| 12 | 1018.7 | 22.68 | 22.78 | 511.40 | 1118.3 | 27.35 | 27.48 | 561.82 | 12 |
| 14 | 1022.0 | 22.83 | 22.93 | 513.08 | 1121.6 | 27.51 | 27.65 | 563.50 | 14 |
| 16 | 1025.4 | 22.98 | 23.08 | 514.76 | 1124.9 | 27.67 | 27.81 | 565.18 | 16 |
| 18 | 1028.7 | 23.13 | 23.23 | 516.44 | 1128.2 | 27.83 | 27.98 | 566.86 | 18 |
| 20 | 1032.0 | 23.28 | 23.38 | 518.12 | 1131.6 | 28.00 | 28.14 | 568.54 | 20 |
| 22 | 1035.3 | 23.43 | 23.53 | 519.80 | 1134.9 | 28.17 | 28.30 | 570.22 | 22 |
| 24 | 1038.6 | 23.58 | 23.68 | 521.48 | 1138.2 | 28.34 | 28.47 | 571.90 | 24 |
| 26 | 1042.0 | 23.73 | 23.84 | 523.16 | 1141.5 | 28.50 | 28.64 | 573.58 | 26 |
| 28 | 1045.3 | 23.88 | 23.99 | 524.85 | 1144.8 | 28.67 | 28.81 | 575.27 | 28 |
| 30 | 1048.6 | 24.04 | 24.14 | 526.53 | 1148.1 | 28.84 | 28.98 | 576.95 | 30 |
| 32 | 1051.9 | 24.19 | 24.30 | 528.21 | 1151.5 | 29.00 | 29.14 | 578.63 | 32 |
| 34 | 1055.2 | 24.34 | 24.45 | 529.89 | 1154.8 | 29.17 | 29.31 | 580.32 | 34 |
| 36 | 1058.6 | 24.49 | 24.60 | 531.57 | 1158.1 | 29.34 | 29.48 | 582.00 | 36 |
| 38 | 1061.9 | 24.64 | 24.76 | 533.25 | 1161.4 | 29.50 | 29.65 | 583.69 | 38 |
| 40 | 1065.2 | 24.80 | 24.91 | 534.93 | 1164.7 | 29.67 | 29.82 | 585.37 | 40 |
| 42 | 1068.5 | 24.95 | 25.06 | 536.61 | 1168.0 | 29.84 | 29.99 | 587.05 | 42 |
| 44 | 1071.8 | 25.11 | 25.22 | 538.29 | 1171.4 | 30.01 | 30.17 | 588.74 | 44 |
| 46 | 1075.2 | 25.27 | 25.38 | 539.97 | 1174.7 | 30.18 | 30.34 | 590.42 | 46 |
| 48 | 1078.5 | 25.43 | 25.54 | 541.65 | 1178.0 | 30.35 | 30.52 | 592.11 | 48 |
| 50 | 1081.8 | 25.59 | 25.70 | 543.33 | 1181.3 | 30.53 | 30.69 | 593.79 | 50 |
| 52 | 1085.1 | 25.74 | 25.86 | 545.01 | 1184.6 | 30.70 | 30.86 | 595.47 | 52 |
| 54 | 1088.4 | 25.90 | 26.02 | 546.69 | 1187.9 | 30.87 | 31.04 | 597.16 | 54 |
| 56 | 1091.8 | 26.06 | 26.18 | 548.37 | 1191.3 | 31.04 | 31.21 | 598.84 | 56 |
| 58 | 1095.1 | 26.22 | 26.34 | 550.06 | 1194.6 | 31.21 | 31.39 | 600.53 | 58 |
| 60 | 1098.4 | 26.38 | 26.50 | 551.74 | 1197.9 | 31.39 | 31.56 | 602.22 | 60 |

| ′ | 12° | | | | 13° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 1197.9 | 31.39 | 31.56 | 602.22 | 1297.3 | 36.83 | 37.07 | 652.87 | 0 |
| 2 | 1201.2 | 31.57 | 31.73 | 603.91 | 1300.6 | 37.02 | 37.26 | 654.56 | 2 |
| 4 | 1204.5 | 31.74 | 31.91 | 605.60 | 1303.9 | 37.21 | 37.46 | 656.25 | 4 |
| 6 | 1207.8 | 31.92 | 32.09 | 607.28 | 1307.2 | 37.40 | 37.65 | 657.93 | 6 |
| 8 | 1211.1 | 32.09 | 32.27 | 608.97 | 1310.5 | 37.59 | 37.85 | 659.62 | 8 |
| 10 | 1214.5 | 32.27 | 32.45 | 610.66 | 1313.8 | 37.79 | 38.04 | 661.31 | 10 |
| 12 | 1217.8 | 32.45 | 32.63 | 612.35 | 1317.2 | 37.98 | 38.23 | 663.00 | 12 |
| 14 | 1221.1 | 32.62 | 32.81 | 614.04 | 1320.5 | 38.17 | 38.43 | 664.69 | 14 |
| 16 | 1224.4 | 32.80 | 32.99 | 615.72 | 1323.8 | 38.36 | 38.62 | 666.37 | 16 |
| 18 | 1227.7 | 32.97 | 33.17 | 617.41 | 1327.1 | 38.55 | 38.82 | 668.06 | 18 |
| 20 | 1231.0 | 33.15 | 33.35 | 619.10 | 1330.4 | 38.75 | 39.01 | 669.75 | 20 |
| 22 | 1234.3 | 33.33 | 33.53 | 620.79 | 1333.7 | 38.95 | 39.20 | 671.44 | 22 |
| 24 | 1237.7 | 33.51 | 33.72 | 622.48 | 1337.0 | 39.15 | 39.40 | 673.13 | 24 |
| 26 | 1241.0 | 33.69 | 33.90 | 624.16 | 1340.3 | 39.35 | 39.60 | 674.81 | 26 |
| 28 | 1244.3 | 33.87 | 34.09 | 625.85 | 1343.6 | 39.54 | 39.80 | 676.51 | 28 |
| 30 | 1247.6 | 34.06 | 34.27 | 627.55 | 1346.9 | 39.74 | 40.00 | 678.20 | 30 |
| 32 | 1250.9 | 34.24 | 34.45 | 629.24 | 1350.3 | 39.94 | 40.19 | 679.89 | 32 |
| 34 | 1254.2 | 34.42 | 34.64 | 630.93 | 1353.6 | 40.13 | 40.39 | 681.58 | 34 |
| 36 | 1257.5 | 34.60 | 34.82 | 632.61 | 1356.9 | 40.33 | 40.59 | 683.26 | 36 |
| 38 | 1260.8 | 34.78 | 35.01 | 634.30 | 1360.2 | 40.52 | 40.79 | 684.95 | 38 |
| 40 | 1264.2 | 34.97 | 35.19 | 635.99 | 1363.5 | 40.71 | 40.99 | 686.64 | 40 |
| 42 | 1267.5 | 35.16 | 35.37 | 637.68 | 1366.8 | 40.91 | 41.19 | 688.33 | 42 |
| 44 | 1270.8 | 35.34 | 35.56 | 639.37 | 1370.1 | 41.11 | 41.40 | 690.02 | 44 |
| 46 | 1274.1 | 35.53 | 35.75 | 641.05 | 1373.4 | 41.31 | 41.60 | 691.70 | 46 |
| 48 | 1277.4 | 35.71 | 35.94 | 642.74 | 1376.7 | 41.51 | 41.81 | 693.39 | 48 |
| 50 | 1280.7 | 35.90 | 36.13 | 644.43 | 1380.0 | 41.71 | 42.01 | 695.08 | 50 |
| 52 | 1284.0 | 36.09 | 36.31 | 646.12 | 1383.4 | 41.91 | 42.21 | 696.77 | 52 |
| 54 | 1287.4 | 36.27 | 36.50 | 647.81 | 1386.7 | 42.11 | 42.42 | 698.46 | 54 |
| 56 | 1290.7 | 36.46 | 36.69 | 649.49 | 1390.0 | 42.31 | 42.62 | 700.14 | 56 |
| 58 | 1294.0 | 36.64 | 36.88 | 651.18 | 1393.3 | 42.51 | 42.83 | 701.83 | 58 |
| 60 | 1297.3 | 36.83 | 37.07 | 652.87 | 1396.6 | 42.71 | 43.03 | 703.53 | 60 |

| ′ | 14° | | | | 15° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 1396.6 | 42.71 | 43.03 | 703.53 | 1495.9 | 49.02 | 49.44 | 754.35 | 0 |
| 2 | 1399.9 | 42.92 | 43.23 | 705.23 | 1499.2 | 49.24 | 49.66 | 756.05 | 2 |
| 4 | 1403.2 | 43.12 | 43.44 | 706.92 | 1502.5 | 49.46 | 49.89 | 757.74 | 4 |
| 6 | 1406.5 | 43.33 | 43.65 | 708.62 | 1505.8 | 49.68 | 50.11 | 759.44 | 6 |
| 8 | 1409.8 | 43.53 | 43.86 | 710.31 | 1509.1 | 49.90 | 50.34 | 761.13 | 8 |
| 10 | 1413.1 | 43.74 | 44.07 | 712.01 | 1512.4 | 50.12 | 50.56 | 762.83 | 10 |
| 12 | 1416.5 | 43.94 | 44.28 | 713.71 | 1515.7 | 50.34 | 50.78 | 764.53 | 12 |
| 14 | 1419.8 | 44.15 | 44.49 | 715.40 | 1519.0 | 50.56 | 51.01 | 766.22 | 14 |
| 16 | 1423.1 | 44.35 | 44.70 | 717.10 | 1522.3 | 50.78 | 51.23 | 767.92 | 16 |
| 18 | 1426.4 | 44.56 | 44.91 | 718.79 | 1525.6 | 51.00 | 51.46 | 769.61 | 18 |
| 20 | 1429.7 | 44.77 | 45.12 | 720.49 | 1528.9 | 51.22 | 51.68 | 771.31 | 20 |
| 22 | 1433.0 | 44.98 | 45.33 | 722.20 | 1532.2 | 51.44 | 51.90 | 773.01 | 22 |
| 24 | 1436.3 | 45.19 | 45.54 | 723.89 | 1535.5 | 51.67 | 52.13 | 774.70 | 24 |
| 26 | 1439.6 | 45.40 | 45.76 | 725.59 | 1538.8 | 51.89 | 52.36 | 776.40 | 26 |
| 28 | 1442.9 | 45.61 | 45.97 | 727.28 | 1542.1 | 52.12 | 52.59 | 778.09 | 28 |
| 30 | 1446.2 | 45.82 | 46.18 | 728.97 | 1545.4 | 52.34 | 52.82 | 779.79 | 30 |
| 32 | 1449.6 | 46.03 | 46.40 | 730.66 | 1548.7 | 52.57 | 53.05 | 781.49 | 32 |
| 34 | 1452.9 | 46.24 | 46.61 | 732.35 | 1552.0 | 52.79 | 53.28 | 783.19 | 34 |
| 36 | 1456.2 | 46.45 | 46.82 | 734.05 | 1555.3 | 53.02 | 53.51 | 784.89 | 36 |
| 38 | 1459.5 | 46.66 | 47.04 | 735.74 | 1558.6 | 53.24 | 53.74 | 786.59 | 38 |
| 40 | 1462.8 | 46.87 | 47.25 | 737.43 | 1561.9 | 53.47 | 53.97 | 788.29 | 40 |
| 42 | 1466.1 | 47.08 | 47.46 | 739.12 | 1565.2 | 53.69 | 54.20 | 789.99 | 42 |
| 44 | 1469.4 | 47.30 | 47.68 | 740.81 | 1568.5 | 53.92 | 54.44 | 791.69 | 44 |
| 46 | 1472.7 | 47.51 | 47.90 | 742.51 | 1571.8 | 54.15 | 54.67 | 793.39 | 46 |
| 48 | 1476.0 | 47.73 | 48.12 | 744.20 | 1575.1 | 54.38 | 54.91 | 795.09 | 48 |
| 50 | 1479.3 | 47.94 | 48.34 | 745.89 | 1578.4 | 54.61 | 55.14 | 796.79 | 50 |
| 52 | 1482.7 | 48.16 | 48.56 | 747.58 | 1581.7 | 54.84 | 55.37 | 798.49 | 52 |
| 54 | 1486.0 | 48.37 | 48.78 | 749.27 | 1585.0 | 55.07 | 55.61 | 800.19 | 54 |
| 56 | 1489.3 | 48.59 | 49.00 | 750.97 | 1588.3 | 55.30 | 55.84 | 801.89 | 56 |
| 58 | 1492.6 | 48.80 | 49.22 | 752.66 | 1591.6 | 55.53 | 56.08 | 803.59 | 58 |
| 60 | 1495.9 | 49.02 | 49.44 | 754.35 | 1594.9 | 55.76 | 56.31 | 805.29 | 60 |

| ′ | 16° | | | | 17° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 1594.9 | 55.76 | 56.31 | 805.29 | 1693.9 | 62.94 | 63.64 | 856.35 | 0 |
| 2 | 1598.2 | 55.99 | 56.54 | 806.99 | 1697.2 | 63.18 | 63.89 | 858.05 | 2 |
| 4 | 1601.5 | 56.23 | 56.78 | 808.64 | 1700.5 | 63.43 | 64.15 | 859.76 | 4 |
| 6 | 1604.8 | 56.46 | 57.02 | 810.39 | 1703.8 | 63.68 | 64.40 | 861.46 | 6 |
| 8 | 1608.1 | 56.70 | 57.26 | 812.09 | 1707.1 | 63.93 | 64.66 | 863.16 | 8 |
| 10 | 1611.4 | 56.93 | 57.50 | 813.79 | 1710.4 | 64.18 | 64.91 | 864.87 | 10 |
| 12 | 1614.7 | 57.17 | 57.74 | 815.49 | 1713.7 | 64.42 | 65.16 | 866.57 | 12 |
| 14 | 1618.0 | 57.40 | 57.98 | 817.19 | 1716.9 | 64.67 | 65.42 | 868.27 | 14 |
| 16 | 1621.3 | 57.64 | 58.22 | 818.89 | 1720.2 | 64.92 | 65.67 | 869.98 | 16 |
| 18 | 1624.6 | 57.87 | 58.46 | 820.59 | 1723.5 | 65.17 | 65.93 | 871.68 | 18 |
| 20 | 1627.9 | 58.11 | 58.70 | 822.29 | 1726.8 | 65.42 | 66.18 | 873.38 | 20 |
| 22 | 1631.2 | 58.34 | 58.94 | 823.99 | 1730.1 | 65.67 | 66.43 | 875.09 | 22 |
| 24 | 1634.5 | 58.58 | 59.19 | 825.69 | 1733.4 | 65.93 | 66.69 | 876.79 | 24 |
| 26 | 1637.8 | 58.82 | 59.43 | 827.39 | 1736.7 | 66.18 | 66.95 | 878.49 | 26 |
| 28 | 1641.1 | 59.06 | 59.68 | 829.09 | 1740.0 | 66.44 | 67.21 | 880.20 | 28 |
| 30 | 1644.4 | 59.30 | 59.92 | 830.79 | 1743.3 | 66.69 | 67.47 | 881.90 | 30 |
| 32 | 1647.7 | 59.54 | 60.16 | 832.49 | 1746.6 | 66.94 | 67.72 | 883.61 | 32 |
| 34 | 1651.0 | 59.78 | 60.41 | 834.20 | 1749.9 | 67.20 | 67.98 | 885.32 | 34 |
| 36 | 1654.3 | 60.02 | 60.65 | 835.90 | 1753.2 | 67.45 | 68.24 | 887.02 | 36 |
| 38 | 1657.6 | 60.26 | 60.90 | 837.61 | 1756.5 | 67.71 | 68.50 | 888.73 | 38 |
| 40 | 1660.9 | 60.50 | 61.14 | 839.31 | 1759.8 | 67.96 | 68.76 | 890.44 | 40 |
| 42 | 1664.2 | 60.74 | 61.39 | 841.01 | 1763.1 | 68.21 | 69.03 | 892.15 | 42 |
| 44 | 1667.5 | 60.99 | 61.64 | 842.72 | 1766.3 | 68.47 | 69.29 | 893.86 | 44 |
| 46 | 1670.8 | 61.23 | 61.89 | 844.42 | 1769.6 | 68.73 | 69.56 | 895.56 | 46 |
| 48 | 1674.1 | 61.48 | 62.14 | 846.13 | 1772.9 | 68.99 | 69.82 | 897.27 | 48 |
| 50 | 1677.4 | 61.72 | 62.39 | 847.83 | 1776.2 | 69.25 | 70.09 | 898.98 | 50 |
| 52 | 1680.7 | 61.96 | 62.64 | 849.53 | 1779.5 | 69.50 | 70.36 | 900.69 | 52 |
| 54 | 1684.0 | 62.21 | 62.89 | 851.24 | 1782.8 | 69.76 | 70.62 | 902.40 | 54 |
| 56 | 1687.3 | 62.45 | 63.14 | 852.94 | 1786.1 | 70.02 | 70.89 | 904.10 | 56 |
| 58 | 1690.6 | 62.70 | 63.39 | 854.65 | 1789.4 | 70.28 | 71.17 | 905.81 | 58 |
| 60 | 1693.9 | 62.94 | 63.64 | 856.35 | 1792.7 | 70.54 | 71.42 | 907.52 | 60 |

| ′ | 18° | | | | 19° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 1792.7 | 70.54 | 71.42 | 907.52 | 1891.5 | 78.58 | 79.65 | 958.86 | 0 |
| 2 | 1796.0 | 70.80 | 71.69 | 909.23 | 1894.8 | 78.86 | 79.94 | 960.57 | 2 |
| 4 | 1799.3 | 71.06 | 71.96 | 910.94 | 1898.1 | 79.13 | 80.22 | 962.30 | 4 |
| 6 | 1802.6 | 71.33 | 72.23 | 912.65 | 1901.3 | 79.41 | 80.51 | 964.00 | 6 |
| 8 | 1805.9 | 71.59 | 72.50 | 914.36 | 1904.6 | 79.68 | 80.79 | 965.72 | 8 |
| 10 | 1809.2 | 71.85 | 72.77 | 916.07 | 1907.9 | 79.96 | 81.08 | 967.43 | 10 |
| 12 | 1812.5 | 72.12 | 73.04 | 917.78 | 1911.2 | 80.24 | 81.37 | 969.15 | 12 |
| 14 | 1815.7 | 72.38 | 73.31 | 919.49 | 1914.5 | 80.51 | 81.65 | 970.86 | 14 |
| 16 | 1819.0 | 72.64 | 73.58 | 921.20 | 1917.8 | 80.79 | 81.94 | 972.58 | 16 |
| 18 | 1822.3 | 72.91 | 73.85 | 922.91 | 1921.0 | 81.07 | 82.22 | 974.29 | 18 |
| 20 | 1825.6 | 73.17 | 74.12 | 924.63 | 1924.3 | 81.35 | 82.51 | 976.01 | 20 |
| 22 | 1828.9 | 73.43 | 74.39 | 926.34 | 1927.6 | 81.63 | 82.80 | 977.72 | 22 |
| 24 | 1832.2 | 73.70 | 74.67 | 928.05 | 1930.9 | 81.91 | 83.09 | 979.44 | 24 |
| 26 | 1835.5 | 73.97 | 74.94 | 929.76 | 1934.2 | 82.20 | 83.38 | 981.15 | 26 |
| 28 | 1838.8 | 74.24 | 75.22 | 931.47 | 1937.5 | 82.48 | 83.67 | 982.86 | 28 |
| 30 | 1842.1 | 74.51 | 75.49 | 933.18 | 1940.7 | 82.76 | 83.97 | 984.58 | 30 |
| 32 | 1845.4 | 74.77 | 75.77 | 934.89 | 1944.0 | 83.05 | 84.26 | 986.30 | 32 |
| 34 | 1848.7 | 75.04 | 76.04 | 936.60 | 1947.3 | 83.33 | 84.55 | 988.02 | 34 |
| 36 | 1852.0 | 75.31 | 76.32 | 938.32 | 1950.6 | 83.61 | 84.84 | 989.74 | 36 |
| 38 | 1855.3 | 75.58 | 76.59 | 940.03 | 1953.9 | 83.90 | 85.13 | 991.46 | 38 |
| 40 | 1858.6 | 75.85 | 76.87 | 941.74 | 1957.2 | 84.18 | 85.43 | 993.18 | 40 |
| 42 | 1861.9 | 76.12 | 77.14 | 943.45 | 1960.4 | 84.47 | 85.73 | 994.90 | 42 |
| 44 | 1865.1 | 76.39 | 77.42 | 945.16 | 1963.7 | 84.75 | 86.02 | 996.62 | 44 |
| 46 | 1868.4 | 76.67 | 77.70 | 946.88 | 1967.0 | 85.04 | 86.32 | 998.34 | 46 |
| 48 | 1871.7 | 76.94 | 77.98 | 948.59 | 1970.3 | 85.32 | 86.61 | 1000.0 | 48 |
| 50 | 1875.0 | 77.21 | 78.26 | 950.30 | 1973.6 | 85.61 | 86.91 | 1001.8 | 50 |
| 52 | 1878.3 | 77.49 | 78.53 | 952.01 | 1976.9 | 85.90 | 87.21 | 1003.5 | 52 |
| 54 | 1881.6 | 77.76 | 78.81 | 953.72 | 1980.1 | 86.19 | 87.50 | 1005.2 | 54 |
| 56 | 1884.9 | 78.03 | 79.09 | 955.44 | 1983.4 | 86.47 | 87.80 | 1006.9 | 56 |
| 58 | 1888.2 | 78.31 | 79.37 | 957.15 | 1986.7 | 86.76 | 88.09 | 1008.6 | 58 |
| 60 | 1891.5 | 78.58 | 79.65 | 958.86 | 1990.0 | 87.05 | 88.39 | 1010.4 | 60 |

| ′ | 20° | | | | 21° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 1990.0 | 87.05 | 88.39 | 1010.4 | 2088.5 | 95.95 | 97.58 | 1062.0 | 0 |
| 2 | 1993.3 | 87.34 | 88.69 | 1012.1 | 2091.8 | 96.26 | 97.90 | 1063.7 | 2 |
| 4 | 1996.6 | 87.63 | 88.99 | 1013.8 | 2095.0 | 96.56 | 98.21 | 1065.4 | 4 |
| 6 | 1999.8 | 87.92 | 89.29 | 1015.5 | 2098.3 | 96.87 | 98.53 | 1067.2 | 6 |
| 8 | 2003.1 | 88.21 | 89.59 | 1017.2 | 2101.6 | 97.17 | 98.84 | 1068.9 | 8 |
| 10 | 2006.4 | 88.50 | 89.89 | 1019.0 | 2104.9 | 97.48 | 99.16 | 1070.6 | 10 |
| 12 | 2009.7 | 88.79 | 90.19 | 1020.7 | 2108.1 | 97.79 | 99.48 | 1072.4 | 12 |
| 14 | 2013.0 | 89.08 | 90.49 | 1022.4 | 2111.4 | 98.09 | 99.79 | 1074.1 | 14 |
| 16 | 2016.3 | 89.37 | 90.79 | 1024.1 | 2114.7 | 98.40 | 100.1 | 1075.8 | 16 |
| 18 | 2019.5 | 89.66 | 91.09 | 1025.8 | 2118.0 | 98.70 | 100.4 | 1077.5 | 18 |
| 20 | 2022.8 | 89.96 | 91.40 | 1027.6 | 2121.2 | 99.00 | 100.7 | 1079.3 | 20 |
| 22 | 2026.1 | 90.25 | 91.71 | 1029.3 | 2124.5 | 99.30 | 101.1 | 1081.0 | 22 |
| 24 | 2029.4 | 90.55 | 92.01 | 1031.0 | 2127.8 | 99.60 | 101.4 | 1082.7 | 24 |
| 26 | 2032.7 | 90.85 | 92.32 | 1032.7 | 2131.0 | 99.90 | 101.7 | 1084.4 | 26 |
| 28 | 2036.0 | 91.15 | 92.62 | 1034.4 | 2134.3 | 100.2 | 102.0 | 1086.2 | 28 |
| 30 | 2039.2 | 91.45 | 92.93 | 1036.1 | 2137.6 | 100.5 | 102.3 | 1087.9 | 30 |
| 32 | 2042.5 | 91.74 | 93.24 | 1037.9 | 2140.9 | 100.8 | 102.7 | 1089.6 | 32 |
| 34 | 2045.8 | 92.04 | 93.54 | 1039.6 | 2144.1 | 101.1 | 103.0 | 1091.3 | 34 |
| 36 | 2049.1 | 92.34 | 93.85 | 1041.3 | 2147.4 | 101.4 | 103.3 | 1093.1 | 36 |
| 38 | 2052.4 | 92.64 | 94.15 | 1043.0 | 2150.7 | 101.7 | 103.6 | 1094.8 | 38 |
| 40 | 2055.7 | 92.94 | 94.46 | 1044.8 | 2154.0 | 102.1 | 104.0 | 1096.5 | 40 |
| 42 | 2058.9 | 93.24 | 94.78 | 1046.5 | 2157.2 | 102.4 | 104.3 | 1098.3 | 42 |
| 44 | 2062.2 | 93.54 | 95.09 | 1048.2 | 2160.5 | 102.7 | 104.6 | 1100.0 | 44 |
| 46 | 2065.5 | 93.84 | 95.40 | 1049.9 | 2163.8 | 103.0 | 104.9 | 1101.7 | 46 |
| 48 | 2068.8 | 94.14 | 95.71 | 1051.7 | 2167.1 | 103.3 | 105.3 | 1103.4 | 48 |
| 50 | 2072.1 | 94.44 | 96.03 | 1053.4 | 2170.3 | 103.6 | 105.6 | 1105.2 | 50 |
| 52 | 2075.4 | 94.74 | 96.34 | 1055.1 | 2173.6 | 103.9 | 105.9 | 1106.9 | 52 |
| 54 | 2078.6 | 95.04 | 96.65 | 1056.8 | 2176.9 | 104.2 | 106.3 | 1108.6 | 54 |
| 56 | 2081.9 | 95.34 | 96.96 | 1058.6 | 2180.1 | 104.5 | 106.6 | 1110.3 | 56 |
| 58 | 2085.2 | 95.64 | 97.27 | 1060.3 | 2183.4 | 104.8 | 106.9 | 1112.1 | 58 |
| 60 | 2088.5 | 95.95 | 97.58 | 1062.0 | 2186.7 | 105.2 | 107.2 | 1113.8 | 60 |

| ′ | 22° | | | | 23° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 2186.7 | 105.2 | 107.2 | 1113.8 | 2284.8 | 115.0 | 117.4 | 1165.8 | 0 |
| 2 | 2190.0 | 105.6 | 107.6 | 1115.5 | 2288.1 | 115.3 | 117.7 | 1167.5 | 2 |
| 4 | 2193.2 | 105.9 | 107.9 | 1117.3 | 2291.3 | 115.7 | 118.1 | 1169.2 | 4 |
| 6 | 2196.5 | 106.2 | 108.2 | 1119.0 | 2294.6 | 116.0 | 118.4 | 1171.0 | 6 |
| 8 | 2199.8 | 106.5 | 108.6 | 1120.7 | 2297.8 | 116.4 | 118.8 | 1172.7 | 8 |
| 10 | 2203.0 | 106.8 | 108.9 | 1122.4 | 2301.1 | 116.7 | 119.1 | 1174.4 | 10 |
| 12 | 2206.3 | 107.1 | 109.2 | 1124.2 | 2304.4 | 117.0 | 119.5 | 1176.2 | 12 |
| 14 | 2209.6 | 107.4 | 109.6 | 1125.9 | 2307.6 | 117.4 | 119.8 | 1177.9 | 14 |
| 16 | 2212.9 | 107.7 | 109.9 | 1127.6 | 2310.9 | 117.7 | 120.2 | 1179.7 | 16 |
| 18 | 2216.1 | 108.0 | 110.2 | 1129.4 | 2314.1 | 118.1 | 120.5 | 1181.4 | 18 |
| 20 | 2219.4 | 108.4 | 110.6 | 1131.1 | 2317.4 | 118.4 | 120.9 | 1183.1 | 20 |
| 22 | 2222.7 | 108.7 | 110.9 | 1132.8 | 2320.7 | 118.7 | 121.2 | 1184.9 | 22 |
| 24 | 2225.9 | 109.0 | 111.2 | 1134.6 | 2323.9 | 119.1 | 121.6 | 1186.6 | 24 |
| 26 | 2229.2 | 109.4 | 111.6 | 1136.3 | 2327.2 | 119.4 | 121.9 | 1188.4 | 26 |
| 28 | 2232.5 | 109.7 | 111.9 | 1138.0 | 2330.4 | 119.8 | 122.3 | 1190.1 | 28 |
| 30 | 2235.7 | 110.0 | 112.3 | 1139.7 | 2333.7 | 120.1 | 122.6 | 1191.8 | 30 |
| 32 | 2239.0 | 110.4 | 112.6 | 1141.5 | 2337.0 | 120.4 | 123.0 | 1193.6 | 32 |
| 34 | 2242.3 | 110.7 | 112.9 | 1143.2 | 2340.2 | 120.8 | 123.3 | 1195.3 | 34 |
| 36 | 2245.6 | 111.0 | 113.3 | 1144.9 | 2343.5 | 121.1 | 123.7 | 1197.1 | 36 |
| 38 | 2248.8 | 111.4 | 113.6 | 1146.7 | 2346.7 | 121.5 | 124.1 | 1198.8 | 38 |
| 40 | 2252.1 | 111.7 | 113.9 | 1148.4 | 2350.0 | 121.8 | 124.4 | 1200.5 | 40 |
| 42 | 2255.4 | 112.0 | 114.3 | 1150.1 | 2353.3 | 122.1 | 124.8 | 1202.3 | 42 |
| 44 | 2258.6 | 112.3 | 114.6 | 1151.9 | 2356.5 | 122.5 | 125.1 | 1204.0 | 44 |
| 46 | 2261.9 | 112.7 | 115.0 | 1153.6 | 2359.8 | 122.8 | 125.5 | 1205.8 | 46 |
| 48 | 2265.2 | 113.0 | 115.3 | 1155.4 | 2363.0 | 123.2 | 125.8 | 1207.5 | 48 |
| 50 | 2268.4 | 113.3 | 115.7 | 1157.1 | 2366.3 | 123.5 | 126.2 | 1209.2 | 50 |
| 52 | 2271.7 | 113.7 | 116.0 | 1158.8 | 2369.6 | 123.8 | 126.6 | 1211.0 | 52 |
| 54 | 2275.0 | 114.0 | 116.3 | 1160.6 | 2372.8 | 124.2 | 126.9 | 1212.7 | 54 |
| 56 | 2278.3 | 114.3 | 116.7 | 1162.3 | 2376.1 | 124.5 | 127.3 | 1214.5 | 56 |
| 58 | 2281.5 | 114.7 | 117.0 | 1164.0 | 2379.3 | 124.9 | 127.6 | 1216.2 | 58 |
| 60 | 2284.8 | 115.0 | 117.4 | 1165.8 | 2382.6 | 125.2 | 128.0 | 1218.0 | 60 |

| ′ | 24° | | | | 25° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 2382.6 | 125.2 | 128.0 | 1218.0 | 2480.4 | 135.8 | 139.1 | 1270.3 | 0 |
| 2 | 2385.9 | 125.5 | 128.4 | 1219.7 | 2483.6 | 136.2 | 139.5 | 1272.0 | 2 |
| 4 | 2389.1 | 125.9 | 128.7 | 1221.4 | 2486.9 | 136.5 | 139.9 | 1273.8 | 4 |
| 6 | 2392.4 | 126.2 | 129.1 | 1223.2 | 2490.1 | 136.9 | 140.3 | 1275.5 | 6 |
| 8 | 2395.6 | 126.6 | 129.5 | 1224.9 | 2493.4 | 137.2 | 140.6 | 1277.3 | 8 |
| 10 | 2398.9 | 126.9 | 129.8 | 1226.7 | 2496.6 | 137.6 | 141.0 | 1279.0 | 10 |
| 12 | 2402.2 | 127.3 | 130.2 | 1228.4 | 2499.9 | 138.0 | 141.4 | 1280.8 | 12 |
| 14 | 2405.4 | 127.6 | 130.6 | 1230.2 | 2503.1 | 138.3 | 141.8 | 1282.5 | 14 |
| 16 | 2408.7 | 128.0 | 130.9 | 1231.9 | 2506.4 | 138.7 | 142.2 | 1284.3 | 16 |
| 18 | 2411.9 | 128.3 | 131.3 | 1233.6 | 2509.6 | 139.0 | 142.5 | 1286.1 | 18 |
| 20 | 2415.2 | 128.7 | 131.7 | 1235.4 | 2512.9 | 139.4 | 142.9 | 1287.8 | 20 |
| 22 | 2418.5 | 129.0 | 132.0 | 1237.1 | 2516.1 | 139.8 | 143.3 | 1289.6 | 22 |
| 24 | 2421.7 | 129.4 | 132.4 | 1238.9 | 2519.4 | 140.1 | 143.7 | 1291.3 | 24 |
| 26 | 2425.0 | 129.7 | 132.8 | 1240.6 | 2522.6 | 140.5 | 144.1 | 1293.1 | 26 |
| 28 | 2428.2 | 130.1 | 133.1 | 1242.4 | 2525.9 | 140.8 | 144.5 | 1294.8 | 28 |
| 30 | 2431.5 | 130.4 | 133.5 | 1244.1 | 2529.1 | 141.2 | 144.9 | 1296.6 | 30 |
| 32 | 2434.8 | 130.8 | 133.9 | 1245.8 | 2532.4 | 141.6 | 145.3 | 1298.3 | 32 |
| 34 | 2438.0 | 131.1 | 134.2 | 1247.6 | 2535.6 | 142.0 | 145.6 | 1300.1 | 34 |
| 36 | 2441.3 | 131.5 | 134.6 | 1249.3 | 2538.9 | 142.3 | 146.0 | 1301.8 | 36 |
| 38 | 2444.5 | 131.8 | 135.0 | 1251.1 | 2542.1 | 142.7 | 146.4 | 1303.6 | 38 |
| 40 | 2447.8 | 132.2 | 135.4 | 1252.8 | 2545.4 | 143.1 | 146.8 | 1305.3 | 40 |
| 42 | 2451.1 | 132.6 | 135.7 | 1254.6 | 2548.6 | 143.5 | 147.2 | 1307.1 | 42 |
| 44 | 2454.3 | 132.9 | 136.1 | 1256.3 | 2551.9 | 143.8 | 147.6 | 1308.8 | 44 |
| 46 | 2457.6 | 133.3 | 136.5 | 1258.1 | 2555.1 | 144.2 | 148.0 | 1310.6 | 46 |
| 48 | 2460.8 | 133.6 | 136.9 | 1259.8 | 2558.4 | 144.5 | 148.4 | 1312.4 | 48 |
| 50 | 2464.1 | 134.0 | 137.2 | 1261.5 | 2561.6 | 144.9 | 148.8 | 1314.1 | 50 |
| 52 | 2467.4 | 134.4 | 137.6 | 1263.3 | 2564.9 | 145.3 | 149.2 | 1315.9 | 52 |
| 54 | 2470.6 | 134.7 | 138.0 | 1265.0 | 2568.1 | 145.7 | 149.5 | 1317.6 | 54 |
| 56 | 2473.9 | 135.1 | 138.4 | 1266.8 | 2571.4 | 146.0 | 149.9 | 1319.4 | 56 |
| 58 | 2477.1 | 135.4 | 138.7 | 1268.5 | 2574.6 | 146.4 | 150.3 | 1321.1 | 58 |
| 60 | 2480.4 | 135.8 | 139.1 | 1270.3 | 2577.9 | 146.8 | 150.7 | 1322.9 | 60 |

| ′ | 26° | | | | 27° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 2577.9 | 146.8 | 150.7 | 1322.9 | 2675.3 | 158.3 | 162.8 | 1375.6 | 0 |
| 2 | 2581.1 | 147.1 | 151.1 | 1324.6 | 2678.5 | 158.6 | 163.2 | 1377.4 | 2 |
| 4 | 2584.4 | 147.5 | 151.5 | 1326.4 | 2681.8 | 159.0 | 163.7 | 1379.2 | 4 |
| 6 | 2587.6 | 147.9 | 151.9 | 1328.1 | 2685.0 | 159.4 | 164.1 | 1380.9 | 6 |
| 8 | 2590.9 | 148.3 | 152.3 | 1329.9 | 2688.2 | 159.8 | 164.5 | 1382.7 | 8 |
| 10 | 2594.1 | 148.7 | 152.7 | 1331.6 | 2691.5 | 160.2 | 164.9 | 1384.5 | 10 |
| 12 | 2597.4 | 149.1 | 153.1 | 1333.4 | 2694.7 | 160.6 | 165.3 | 1386.2 | 12 |
| 14 | 2600.6 | 149.4 | 153.5 | 1335.2 | 2698.0 | 161.0 | 165.7 | 1388.0 | 14 |
| 16 | 2603.9 | 149.8 | 153.9 | 1336.9 | 2701.2 | 161.4 | 166.1 | 1389.8 | 16 |
| 18 | 2607.1 | 150.2 | 154.3 | 1338.7 | 2704.4 | 161.8 | 166.5 | 1391.5 | 18 |
| 20 | 2610.4 | 150.6 | 154.7 | 1340.4 | 2707.7 | 162.2 | 167.0 | 1393.3 | 20 |
| 22 | 2613.6 | 151.0 | 155.1 | 1342.2 | 2710.9 | 162.6 | 167.4 | 1395.0 | 22 |
| 24 | 2616.9 | 151.4 | 155.5 | 1343.9 | 2714.1 | 163.0 | 167.8 | 1396.8 | 24 |
| 26 | 2620.1 | 151.7 | 155.9 | 1345.7 | 2717.4 | 163.4 | 168.2 | 1398.6 | 26 |
| 28 | 2623.4 | 152.1 | 156.3 | 1347.4 | 2720.6 | 163.8 | 168.6 | 1400.3 | 28 |
| 30 | 2626.6 | 152.5 | 156.7 | 1349.2 | 2723.8 | 164.2 | 169.1 | 1402.1 | 30 |
| 32 | 2629.8 | 152.9 | 157.1 | 1351.0 | 2727.1 | 164.6 | 169.5 | 1403.9 | 32 |
| 34 | 2633.1 | 153.3 | 157.5 | 1352.7 | 2730.3 | 165.0 | 169.9 | 1405.6 | 34 |
| 36 | 2636.3 | 153.7 | 157.9 | 1354.5 | 2733.6 | 165.4 | 170.3 | 1407.4 | 36 |
| 38 | 2639.6 | 154.0 | 158.3 | 1356.2 | 2736.8 | 165.8 | 170.8 | 1409.2 | 38 |
| 40 | 2642.8 | 154.4 | 158.7 | 1358.0 | 2740.0 | 166.2 | 171.2 | 1410.9 | 40 |
| 42 | 2646.1 | 154.8 | 159.1 | 1359.8 | 2743.3 | 166.6 | 171.6 | 1412.7 | 42 |
| 44 | 2649.3 | 155.2 | 159.5 | 1361.5 | 2746.5 | 167.0 | 172.0 | 1414.5 | 44 |
| 46 | 2652.6 | 155.6 | 160.0 | 1363.3 | 2749.7 | 167.4 | 172.5 | 1416.3 | 46 |
| 48 | 2655.8 | 156.0 | 160.4 | 1365.1 | 2753.0 | 167.8 | 172.9 | 1418.0 | 48 |
| 50 | 2659.1 | 156.3 | 160.8 | 1366.8 | 2756.2 | 168.2 | 173.3 | 1419.8 | 50 |
| 52 | 2662.3 | 156.7 | 161.2 | 1368.6 | 2759.5 | 168.6 | 173.7 | 1421.6 | 52 |
| 54 | 2665.6 | 157.1 | 161.6 | 1370.4 | 2762.7 | 169.0 | 174.1 | 1423.3 | 54 |
| 56 | 2668.8 | 157.5 | 162.0 | 1372.1 | 2765.9 | 169.4 | 174.6 | 1425.1 | 56 |
| 58 | 2672.1 | 157.9 | 162.4 | 1373.9 | 2769.2 | 169.8 | 175.0 | 1426.9 | 58 |
| 60 | 2675.3 | 158.3 | 162.8 | 1375.6 | 2772.4 | 170.2 | 175.4 | 1428.6 | 60 |

| ′ | 28° | | | | 29° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 2772.4 | 170.2 | 175.4 | 1428.6 | 2869.4 | 182.5 | 188.5 | 1481.9 | 0 |
| 2 | 2775.6 | 170.6 | 175.8 | 1430.4 | 2872.6 | 182.9 | 189.0 | 1483.7 | 2 |
| 4 | 2778.9 | 171.0 | 176.3 | 1432.2 | 2875.8 | 183.3 | 189.4 | 1485.4 | 4 |
| 6 | 2782.1 | 171.4 | 176.7 | 1434.0 | 2879.1 | 183.7 | 189.9 | 1487.2 | 6 |
| 8 | 2785.3 | 171.8 | 177.1 | 1435.7 | 2882.3 | 184.2 | 190.3 | 1489.0 | 8 |
| 10 | 2788.6 | 172.2 | 177.6 | 1437.5 | 2885.5 | 184.6 | 190.8 | 1490.8 | 10 |
| 12 | 2791.8 | 172.6 | 178.0 | 1439.3 | 2888.7 | 185.0 | 191.2 | 1492.6 | 12 |
| 14 | 2795.0 | 173.0 | 178.4 | 1441.1 | 2892.0 | 185.4 | 191.7 | 1494.3 | 14 |
| 16 | 2798.3 | 173.4 | 178.9 | 1442.8 | 2895.2 | 185.8 | 192.1 | 1496.1 | 16 |
| 18 | 2801.5 | 173.8 | 179.3 | 1444.6 | 2898.4 | 186.3 | 192.5 | 1497.9 | 18 |
| 20 | 2804.7 | 174.3 | 179.7 | 1446.4 | 2901.6 | 186.7 | 193.0 | 1499.7 | 20 |
| 22 | 2808.0 | 174.7 | 180.2 | 1448.2 | 2904.8 | 187.1 | 193.5 | 1501.5 | 22 |
| 24 | 2811.2 | 175.1 | 180.6 | 1449.9 | 2908.1 | 187.5 | 193.9 | 1503.2 | 24 |
| 26 | 2814.4 | 175.5 | 181.0 | 1451.7 | 2911.3 | 188.0 | 194.4 | 1505.0 | 26 |
| 28 | 2817.7 | 175.9 | 181.5 | 1453.5 | 2914.5 | 188.4 | 194.8 | 1506.8 | 28 |
| 30 | 2820.9 | 176.3 | 181.9 | 1455.2 | 2917.7 | 188.8 | 195.3 | 1508.6 | 30 |
| 32 | 2824.1 | 176.7 | 182.3 | 1457.0 | 2921.0 | 189.2 | 195.7 | 1510.4 | 32 |
| 34 | 2827.4 | 177.1 | 182.8 | 1458.8 | 2924.2 | 189.7 | 196.2 | 1512.1 | 34 |
| 36 | 2830.6 | 177.5 | 183.2 | 1460.6 | 2927.4 | 190.1 | 196.7 | 1513.9 | 36 |
| 38 | 2833.8 | 177.9 | 183.6 | 1462.3 | 2930.6 | 190.5 | 197.1 | 1515.7 | 38 |
| 40 | 2837.1 | 178.4 | 184.1 | 1464.1 | 2933.9 | 190.9 | 197.6 | 1517.5 | 40 |
| 42 | 2840.3 | 178.8 | 184.5 | 1465.9 | 2937.1 | 191.4 | 198.0 | 1519.3 | 42 |
| 44 | 2843.5 | 179.2 | 185.0 | 1467.7 | 2940.3 | 191.9 | 198.5 | 1521.0 | 44 |
| 46 | 2846.8 | 179.6 | 185.4 | 1469.5 | 2943.5 | 192.4 | 198.9 | 1522.8 | 46 |
| 48 | 2850.0 | 180.0 | 185.9 | 1471.2 | 2946.8 | 192.8 | 199.4 | 1524.6 | 48 |
| 50 | 2853.2 | 180.4 | 186.3 | 1473.0 | 2950.0 | 193.2 | 199.8 | 1526.4 | 50 |
| 52 | 2856.5 | 180.8 | 186.8 | 1474.8 | 2953.2 | 193.6 | 200.3 | 1528.2 | 52 |
| 54 | 2859.7 | 181.2 | 187.2 | 1476.6 | 2956.4 | 194.0 | 200.8 | 1530.0 | 54 |
| 56 | 2862.9 | 181.6 | 187.6 | 1478.3 | 2959.6 | 194.4 | 201.2 | 1531.7 | 56 |
| 58 | 2866.2 | 182.0 | 188.1 | 1480.1 | 2962.9 | 194.8 | 201.7 | 1533.5 | 58 |
| 60 | 2869.4 | 182.5 | 188.5 | 1481.9 | 2966.1 | 195.2 | 202.1 | 1535.3 | 60 |

| ′ | 30° |  |  |  | 31° |  |  |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | L. C. | M. | E. | T. | L. C. | M. | E. | T. |  |
| 0 | 2966.1 | 195.2 | 202.1 | 1535.3 | 3062.6 | 208.4 | 216.3 | 1589.0 | 0 |
| 2 | 2969.3 | 195.6 | 202.6 | 1537.1 | 3065.8 | 208.8 | 216.8 | 1590.8 | 2 |
| 4 | 2972.5 | 196.1 | 203.1 | 1538.9 | 3069.0 | 209.3 | 217.2 | 1592.6 | 4 |
| 6 | 2975.7 | 196.5 | 203.5 | 1540.7 | 3072.2 | 209.7 | 217.7 | 1594.4 | 6 |
| 8 | 2979.0 | 197.0 | 204.0 | 1542.5 | 3075.4 | 210.2 | 218.2 | 1596.2 | 8 |
| 10 | 2982.2 | 197.4 | 204.5 | 1544.3 | 3078.6 | 210.6 | 218.7 | 1598.0 | 10 |
| 12 | 2985.4 | 197.8 | 204.9 | 1546.0 | 3081.8 | 211.1 | 219.2 | 1599.8 | 12 |
| 14 | 2988.6 | 198.2 | 205.4 | 1547.8 | 3085.0 | 211.5 | 219.6 | 1601.6 | 14 |
| 16 | 2991.8 | 198.6 | 205.9 | 1549.6 | 3088.3 | 212.0 | 220.1 | 1603.4 | 16 |
| 18 | 2995.0 | 199.1 | 206.3 | 1551.4 | 3091.5 | 212.4 | 220.6 | 1605.2 | 18 |
| 20 | 2998.3 | 199.5 | 206.8 | 1553.2 | 3094.7 | 212.9 | 221.1 | 1607.0 | 20 |
| 22 | 3001.5 | 199.9 | 207.3 | 1555.0 | 3097.9 | 213.3 | 221.6 | 1608.8 | 22 |
| 24 | 3004.7 | 200.4 | 207.7 | 1556.8 | 3101.1 | 213.8 | 222.1 | 1610.6 | 24 |
| 26 | 3007.9 | 200.8 | 208.2 | 1558.6 | 3104.3 | 214.2 | 222.6 | 1612.4 | 26 |
| 28 | 3011.1 | 201.3 | 208.7 | 1560.4 | 3107.5 | 214.7 | 223.0 | 1614.2 | 28 |
| 30 | 3014.3 | 201.7 | 209.1 | 1562.2 | 3110.7 | 215.1 | 223.5 | 1616.0 | 30 |
| 32 | 3017.6 | 202.1 | 209.6 | 1564.0 | 3113.9 | 215.6 | 224.0 | 1617.8 | 32 |
| 34 | 3020.8 | 202.6 | 210.1 | 1565.7 | 3117.1 | 216.0 | 224.5 | 1619.6 | 34 |
| 36 | 3024.0 | 203.0 | 210.5 | 1567.5 | 3120.3 | 216.5 | 225.0 | 1621.4 | 36 |
| 38 | 3027.2 | 203.5 | 211.0 | 1569.3 | 3123.5 | 216.9 | 225.5 | 1623.2 | 38 |
| 40 | 3030.4 | 203.9 | 211.5 | 1571.1 | 3126.7 | 217.4 | 226.0 | 1625.0 | 40 |
| 42 | 3033.6 | 204.3 | 212.0 | 1572.9 | 3129.9 | 217.8 | 226.5 | 1626.8 | 42 |
| 44 | 3036.9 | 204.8 | 212.4 | 1574.7 | 3133.1 | 218.3 | 227.0 | 1628.6 | 44 |
| 46 | 3040.1 | 205.2 | 212.9 | 1576.5 | 3136.4 | 218.7 | 227.5 | 1630.5 | 46 |
| 48 | 3043.3 | 205.7 | 213.4 | 1578.3 | 3139.6 | 219.2 | 228.0 | 1632.3 | 48 |
| 50 | 3046.5 | 206.1 | 213.9 | 1580.1 | 3142.8 | 219.6 | 228.4 | 1634.1 | 50 |
| 52 | 3049.7 | 206.5 | 214.4 | 1581.9 | 3146.0 | 220.1 | 228.9 | 1635.9 | 52 |
| 54 | 3052.9 | 207.0 | 214.8 | 1583.7 | 3149.2 | 220.5 | 229.4 | 1637.7 | 54 |
| 56 | 3056.2 | 207.4 | 215.3 | 1585.5 | 3152.4 | 221.0 | 229.9 | 1639.5 | 56 |
| 58 | 3059.4 | 207.9 | 215.8 | 1587.2 | 3155.6 | 221.5 | 230.4 | 1641.3 | 58 |
| 60 | 3062.6 | 208.4 | 216.3 | 1589.0 | 3158.8 | 222.0 | 230.9 | 1643.1 | 60 |

| ′ | 32° |  |  |  | 33° |  |  |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | L. C. | M. | E. | T. | L. C. | M. | E. | T. |  |
| 0 | 3158.8 | 222.0 | 230.9 | 1643.1 | 3254.9 | 236.0 | 246.1 | 1697.3 | 0 |
| 2 | 3162.0 | 222.5 | 231.4 | 1644.9 | 3258.1 | 236.4 | 246.6 | 1699.1 | 2 |
| 4 | 3165.2 | 222.9 | 231.9 | 1646.7 | 3261.3 | 236.9 | 247.1 | 1700.9 | 4 |
| 6 | 3168.4 | 223.4 | 232.4 | 1648.5 | 3264.5 | 237.4 | 247.7 | 1702.7 | 6 |
| 8 | 3171.6 | 223.8 | 232.9 | 1650.3 | 3267.7 | 237.9 | 248.2 | 1704.5 | 8 |
| 10 | 3174.8 | 224.3 | 233.4 | 1652.1 | 3270.8 | 238.4 | 248.7 | 1706.4 | 10 |
| 12 | 3178.0 | 224.8 | 233.9 | 1653.9 | 3274.0 | 238.9 | 249.2 | 1708.2 | 12 |
| 14 | 3181.2 | 225.2 | 234.4 | 1655.7 | 3277.2 | 239.3 | 249.7 | 1710.0 | 14 |
| 16 | 3184.4 | 225.7 | 234.9 | 1657.5 | 3280.4 | 239.8 | 250.2 | 1711.8 | 16 |
| 18 | 3187.6 | 226.1 | 235.4 | 1659.3 | 3283.6 | 240.3 | 250.8 | 1713.6 | 18 |
| 20 | 3190.8 | 226.6 | 235.9 | 1661.1 | 3286.8 | 240.8 | 251.3 | 1715.5 | 20 |
| 22 | 3194.0 | 227.1 | 236.4 | 1662.9 | 3290.0 | 241.2 | 251.8 | 1717.3 | 22 |
| 24 | 3197.2 | 227.5 | 236.9 | 1664.7 | 3293.2 | 241.7 | 252.3 | 1719.1 | 24 |
| 26 | 3200.4 | 228.0 | 237.4 | 1666.5 | 3296.4 | 242.2 | 252.9 | 1720.9 | 26 |
| 28 | 3203.6 | 228.4 | 237.9 | 1668.3 | 3299.6 | 242.7 | 253.4 | 1722.7 | 28 |
| 30 | 3206.8 | 228.9 | 238.4 | 1670.1 | 3302.7 | 243.2 | 253.9 | 1724.6 | 30 |
| 32 | 3210.0 | 229.4 | 239.0 | 1671.9 | 3305.9 | 243.6 | 254.4 | 1726.4 | 32 |
| 34 | 3213.2 | 229.8 | 239.5 | 1673.7 | 3309.1 | 244.1 | 255.0 | 1728.2 | 34 |
| 36 | 3216.5 | 230.3 | 240.0 | 1675.5 | 3312.3 | 244.6 | 255.5 | 1730.0 | 36 |
| 38 | 3219.7 | 230.7 | 240.5 | 1677.4 | 3315.5 | 245.1 | 256.0 | 1731.8 | 38 |
| 40 | 3222.9 | 231.2 | 241.0 | 1679.2 | 3318.7 | 245.6 | 256.5 | 1733.6 | 40 |
| 42 | 3226.1 | 231.7 | 241.5 | 1681.0 | 3321.9 | 246.0 | 257.1 | 1735.5 | 42 |
| 44 | 3629.3 | 232.2 | 242.0 | 1682.8 | 3325.1 | 246.5 | 257.6 | 1737.3 | 44 |
| 46 | 3232.5 | 232.6 | 242.5 | 1684.6 | 3328.3 | 247.0 | 258.1 | 1739.1 | 46 |
| 48 | 3235.7 | 233.1 | 243.0 | 1686.4 | 3331.5 | 247.5 | 258.6 | 1740.9 | 48 |
| 50 | 3238.9 | 233.5 | 243.5 | 1688.2 | 3334.6 | 248.0 | 259.2 | 1742.7 | 50 |
| 52 | 3242.1 | 234.0 | 244.1 | 1690.0 | 3337.8 | 248.4 | 259.7 | 1744.6 | 52 |
| 51 | 3245.3 | 234.5 | 244.6 | 1691.8 | 3341.0 | 248.9 | 260.2 | 1746.4 | 54 |
| 56 | 3248.5 | 235.0 | 245.1 | 1693.7 | 3344.2 | 249.4 | 260.8 | 1748.2 | 56 |
| 58 | 3251.7 | 235.5 | 245.6 | 1695.5 | 3347.4 | 249.9 | 261.3 | 1750.0 | 58 |
| 60 | 3254.9 | 236.0 | 246.1 | 1697.3 | 3350.6 | 250.4 | 261.8 | 1751.8 | 60 |

| ′ | 34° | | | | 35° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 3350.6 | 250.4 | 261.8 | 1751.8 | 3446.1 | 265.2 | 278.1 | 1806.7 | 0 |
| 2 | 3353.8 | 250.8 | 262.3 | 1753.7 | 3449.3 | 265.7 | 278.6 | 1808.5 | 2 |
| 4 | 3357.0 | 251.2 | 262.9 | 1755.5 | 3452.5 | 266.2 | 279.2 | 1810.3 | 4 |
| 6 | 3360.1 | 251.7 | 263.4 | 1757.3 | 3455.6 | 266.7 | 279.7 | 1812.2 | 6 |
| 8 | 3363.3 | 252.2 | 264.0 | 1759.1 | 3458.8 | 267.2 | 280.3 | 1814.0 | 8 |
| 10 | 3366.5 | 252.7 | 264.5 | 1761.0 | 3462.0 | 267.7 | 280.8 | 1815.8 | 10 |
| 12 | 3369.7 | 253.2 | 265.0 | 1762.8 | 3465.2 | 268.2 | 281.4 | 1817.7 | 12 |
| 14 | 3372.9 | 253.7 | 265.6 | 1764.6 | 3468.3 | 268.7 | 281.9 | 1819.5 | 14 |
| 16 | 3376.1 | 254.2 | 266.1 | 1766.4 | 3471.5 | 269.2 | 282.5 | 1821.3 | 16 |
| 18 | 3379.2 | 254.7 | 266.7 | 1768.3 | 3474.7 | 269.7 | 283.0 | 1823.2 | 18 |
| 20 | 3382.4 | 255.2 | 267.2 | 1770.1 | 3477.9 | 270.2 | 283.6 | 1825.0 | 20 |
| 22 | 3385.6 | 255.7 | 267.7 | 1771.9 | 3481.0 | 270.7 | 284.2 | 1826.8 | 22 |
| 24 | 3388.8 | 256.2 | 268.3 | 1773.7 | 3484.2 | 271.2 | 284.7 | 1828.7 | 24 |
| 26 | 3392.0 | 256.7 | 268.8 | 1775.6 | 3487.4 | 271.7 | 285.3 | 1830.5 | 26 |
| 28 | 3395.2 | 257.2 | 269.3 | 1777.4 | 3490.6 | 272.2 | 285.9 | 1832.3 | 28 |
| 30 | 3398.3 | 257.7 | 269.9 | 1779.2 | 3493.7 | 272.7 | 286.4 | 1834.2 | 30 |
| 32 | 3401.5 | 258.2 | 270.4 | 1781.0 | 3496.9 | 273.2 | 287.0 | 1836.0 | 32 |
| 34 | 3404.7 | 258.7 | 271.0 | 1782.9 | 3500.1 | 273.7 | 287.5 | 1837.8 | 34 |
| 36 | 3407.9 | 259.2 | 271.5 | 1784.7 | 3503.3 | 274.2 | 288.1 | 1839.7 | 36 |
| 38 | 3411.1 | 259.7 | 272.0 | 1786.5 | 3506.5 | 274.7 | 288.7 | 1841.5 | 38 |
| 40 | 3414.3 | 260.2 | 272.6 | 1788.4 | 3509.6 | 275.2 | 289.2 | 1843.4 | 40 |
| 42 | 3417.4 | 260.7 | 273.1 | 1790.2 | 3512.8 | 275.7 | 289.8 | 1845.2 | 42 |
| 44 | 3420.6 | 261.2 | 273.7 | 1792.0 | 3516.0 | 276.2 | 290.4 | 1847.1 | 44 |
| 46 | 3423.8 | 261.7 | 274.2 | 1793.9 | 3519.2 | 276.7 | 290.9 | 1848.9 | 46 |
| 48 | 3427.0 | 262.2 | 274.8 | 1795.7 | 3522.3 | 277.2 | 291.5 | 1850.7 | 48 |
| 50 | 3430.2 | 262.7 | 275.3 | 1797.5 | 3525.5 | 277.7 | 292.0 | 1852.6 | 50 |
| 52 | 3433.4 | 263.2 | 275.9 | 1799.3 | 3528.7 | 278.2 | 292.6 | 1854.4 | 52 |
| 54 | 3436.5 | 263.7 | 276.4 | 1801.2 | 3531.9 | 278.7 | 293.2 | 1856.3 | 54 |
| 56 | 3439.7 | 264.2 | 277.0 | 1803.0 | 3535.0 | 279.2 | 293.7 | 1858.1 | 56 |
| 58 | 3442.9 | 264.7 | 277.5 | 1804.8 | 3538.2 | 279.8 | 294.3 | 1859.9 | 58 |
| 60 | 3446.1 | 265.2 | 278.1 | 1806.7 | 3541.4 | 280.4 | 294.9 | 1861.8 | 60 |

| ′ | 36° | | | | 37° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 3541.4 | 280.4 | 294.9 | 1861.8 | 3636.3 | 296.1 | 312.3 | 1917.3 | 0 |
| 2 | 3544.6 | 280.9 | 295.4 | 1863.6 | 3639.5 | 296.6 | 312.8 | 1919.1 | 2 |
| 4 | 3547.7 | 281.4 | 296.0 | 1865.5 | 3642.6 | 297.1 | 313.4 | 1921.0 | 4 |
| 6 | 3550.9 | 281.9 | 296.6 | 1867.3 | 3645.8 | 297.7 | 314.0 | 1922.8 | 6 |
| 8 | 3554.0 | 282.5 | 297.2 | 1869.2 | 3648.9 | 298.2 | 314.6 | 1924.7 | 8 |
| 10 | 3557.2 | 283.0 | 297.7 | 1871.0 | 3652.1 | 298.7 | 315.2 | 1926.5 | 10 |
| 12 | 3560.4 | 283.5 | 298.3 | 1872.9 | 3655.2 | 299.3 | 315.8 | 1928.4 | 12 |
| 14 | 3563.5 | 284.0 | 298.9 | 1874.7 | 3658.4 | 299.8 | 316.4 | 1930.2 | 14 |
| 16 | 3566.7 | 284.6 | 299.5 | 1876.5 | 3661.6 | 300.3 | 317.0 | 1932.1 | 16 |
| 18 | 3569.9 | 285.1 | 300.0 | 1878.4 | 3664.7 | 300.9 | 317.5 | 1933.9 | 18 |
| 20 | 3573.0 | 285.6 | 300.6 | 1880.2 | 3667.9 | 301.4 | 318.1 | 1935.8 | 20 |
| 22 | 3576.2 | 286.1 | 301.2 | 1882.1 | 3671.0 | 301.9 | 318.7 | 1937.6 | 22 |
| 24 | 3579.4 | 286.7 | 301.8 | 1883.9 | 3674.2 | 302.5 | 319.3 | 1939.5 | 24 |
| 26 | 3582.5 | 287.2 | 302.3 | 1885.8 | 3677.3 | 303.0 | 319.9 | 1941.3 | 26 |
| 28 | 3585.7 | 287.7 | 302.9 | 1887.6 | 3680.5 | 303.5 | 320.5 | 1943.2 | 28 |
| 30 | 3588.8 | 288.2 | 303.5 | 1889.5 | 3683.6 | 304.1 | 321.1 | 1945.0 | 30 |
| 32 | 3592.0 | 288.8 | 304.1 | 1891.3 | 3686.8 | 304.6 | 321.7 | 1946.9 | 32 |
| 34 | 3595.2 | 289.3 | 304.6 | 1893.2 | 3690.0 | 305.1 | 322.3 | 1948.8 | 34 |
| 36 | 3598.3 | 289.8 | 305.2 | 1895.0 | 3693.1 | 305.7 | 322.9 | 1950.6 | 36 |
| 38 | 3601.5 | 290.3 | 305.8 | 1896.9 | 3696.3 | 306.2 | 323.5 | 1952.5 | 38 |
| 40 | 3604.7 | 290.9 | 306.4 | 1898.7 | 3699.4 | 306.7 | 324.2 | 1954.4 | 40 |
| 42 | 3607.8 | 291.4 | 307.0 | 1900.6 | 3702.6 | 307.3 | 324.8 | 1956.2 | 42 |
| 44 | 3611.0 | 291.9 | 307.5 | 1902.4 | 3705.7 | 307.8 | 325.4 | 1958.1 | 44 |
| 46 | 3614.1 | 292.4 | 308.1 | 1904.3 | 3708.9 | 308.3 | 326.0 | 1960.0 | 46 |
| 48 | 3617.3 | 293.0 | 308.7 | 1906.1 | 3712.1 | 308.9 | 326.6 | 1961.8 | 48 |
| 50 | 3620.5 | 293.5 | 309.3 | 1908.0 | 3715.2 | 309.4 | 327.2 | 1963.7 | 50 |
| 52 | 3623.6 | 294.0 | 309.9 | 1909.8 | 3718.4 | 309.9 | 327.8 | 1965.5 | 52 |
| 54 | 3626.8 | 294.5 | 310.5 | 1911.7 | 3721.5 | 310.5 | 328.4 | 1967.4 | 54 |
| 56 | 3630.0 | 295.1 | 311.1 | 1913.5 | 3724.7 | 311.0 | 329.0 | 1969.3 | 56 |
| 58 | 3633.1 | 295.6 | 311.7 | 1915.4 | 3727.8 | 311.6 | 329.6 | 1971.1 | 58 |
| 60 | 3636.3 | 296.1 | 312.3 | 1917.3 | 3731.0 | 312.2 | 330.2 | 1973.0 | 60 |

| ′ | 38° | | | | 39° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 3731.0 | 312.2 | 330.2 | 1973.0 | 3825.5 | 328.7 | 348.7 | 2029.1 | 0 |
| 2 | 3734.1 | 312.7 | 330.8 | 1974.9 | 3828.6 | 329.2 | 349.3 | 2031.0 | 2 |
| 4 | 3737.3 | 313.3 | 331.4 | 1976.7 | 3831.8 | 329.8 | 349.9 | 2032.9 | 4 |
| 6 | 3740.4 | 313.8 | 332.0 | 1978.6 | 3834.9 | 330.3 | 350.6 | 2034.7 | 6 |
| 8 | 3743.6 | 314.4 | 332.6 | 1980.5 | 3838.0 | 330.9 | 351.2 | 2036.6 | 8 |
| 10 | 3746.7 | 314.9 | 333.2 | 1982.3 | 3841.2 | 331.5 | 351.8 | 2038.5 | 10 |
| 12 | 3749.9 | 315.5 | 333.8 | 1984.2 | 3844.3 | 332.0 | 352.4 | 2040.4 | 12 |
| 14 | 3753.0 | 316.0 | 334.5 | 1986.1 | 3847.4 | 332.6 | 353.1 | 2042.3 | 14 |
| 16 | 3756.2 | 316.6 | 335.1 | 1987.9 | 3850.6 | 333.2 | 353.7 | 2044.1 | 16 |
| 18 | 3759.3 | 317.1 | 335.7 | 1989.8 | 3853.7 | 333.7 | 354.3 | 2046.0 | 18 |
| 20 | 3762.5 | 317.7 | 336.3 | 1991.7 | 3856.8 | 334.3 | 354.9 | 2047.9 | 20 |
| 22 | 3765.6 | 318.2 | 336.9 | 1993.6 | 3860.0 | 334.9 | 355.6 | 2049.8 | 22 |
| 24 | 3768.8 | 318.8 | 337.5 | 1995.4 | 3863.1 | 335.4 | 356.2 | 2051.7 | 24 |
| 26 | 3771.9 | 319.3 | 338.1 | 1997.3 | 3866.2 | 336.0 | 356.9 | 2053.5 | 26 |
| 28 | 3775.1 | 319.9 | 338.7 | 1999.2 | 3869.4 | 336.6 | 357.5 | 2055.4 | 28 |
| 30 | 3778.2 | 320.4 | 339.4 | 2001.0 | 3872.5 | 337.1 | 358.1 | 2057.3 | 30 |
| 32 | 3781.4 | 321.0 | 340.0 | 2002.9 | 3875.6 | 337.7 | 358.8 | 2059.2 | 32 |
| 34 | 3784.5 | 321.5 | 340.6 | 2004.8 | 3878.8 | 338.3 | 359.4 | 2061.1 | 34 |
| 36 | 3787.7 | 322.1 | 341.2 | 2006.6 | 3881.9 | 338.8 | 360.1 | 2063.0 | 36 |
| 38 | 3790.8 | 322.6 | 341.8 | 2008.5 | 3885.0 | 339.4 | 360.7 | 2064.8 | 38 |
| 40 | 3794.0 | 323.2 | 342.4 | 2010.4 | 3888.2 | 340.0 | 361.3 | 2066.7 | 40 |
| 42 | 3797.1 | 323.7 | 343.1 | 2012.3 | 3891.3 | 340.5 | 362.0 | 2068.6 | 42 |
| 44 | 3800.3 | 324.3 | 343.7 | 2014.1 | 3894.4 | 341.1 | 362.6 | 2070.5 | 44 |
| 46 | 3803.4 | 324.8 | 344.3 | 2016.0 | 3897.6 | 341.7 | 363.3 | 2072.4 | 46 |
| 48 | 3806.6 | 325.4 | 344.9 | 2017.9 | 3900.7 | 342.2 | 363.9 | 2074.2 | 48 |
| 50 | 3809.7 | 325.9 | 345.6 | 2019.7 | 3903.8 | 342.8 | 364.5 | 2076.1 | 50 |
| 52 | 3812.9 | 326.5 | 346.2 | 2021.6 | 3907.0 | 343.4 | 365.2 | 2078.0 | 52 |
| 54 | 3816.0 | 327.0 | 346.8 | 2023.5 | 3910.1 | 343.9 | 365.8 | 2079.9 | 54 |
| 56 | 3819.2 | 327.6 | 347.4 | 2025.4 | 3913.2 | 344.5 | 366.5 | 2081.8 | 56 |
| 58 | 3822.3 | 328.1 | 348.1 | 2027.2 | 3916.4 | 345.1 | 367.1 | 2083.7 | 58 |
| 60 | 3825.5 | 328.7 | 348.7 | 2029.1 | 3919.5 | 345.6 | 367.7 | 2085.5 | 60 |

| ′ | 40° | | | | 41° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 3919.5 | 345.6 | 367.7 | 2085.5 | 4013.4 | 362.9 | 387.4 | 2142.3 | 0 |
| 2 | 3922.6 | 346.1 | 368.4 | 2087.4 | 4016.5 | 363.4 | 388.1 | 2144.2 | 2 |
| 4 | 3925.8 | 346.7 | 369.0 | 2089.3 | 4019.6 | 364.0 | 388.8 | 2146.1 | 4 |
| 6 | 3928.9 | 347.2 | 369.7 | 2091.2 | 4022.7 | 364.5 | 389.4 | 2148.0 | 6 |
| 8 | 3932.0 | 347.8 | 370.3 | 2093.1 | 4025.9 | 365.1 | 390.1 | 2149.9 | 8 |
| 10 | 3935.1 | 348.4 | 371.0 | 2095.0 | 4029.0 | 365.6 | 390.7 | 2151.9 | 10 |
| 12 | 3938.3 | 348.9 | 371.6 | 2096.9 | 4032.1 | 366.2 | 391.4 | 2153.8 | 12 |
| 14 | 3941.4 | 349.5 | 372.3 | 2098.8 | 4035.2 | 366.8 | 392.1 | 2155.7 | 14 |
| 16 | 3944.5 | 350.1 | 372.9 | 2100.7 | 4038.3 | 367.4 | 392.7 | 2157.6 | 16 |
| 18 | 3947.7 | 350.7 | 373.6 | 2102.6 | 4041.4 | 368.0 | 393.4 | 2159.5 | 18 |
| 20 | 3950.8 | 351.3 | 374.3 | 2104.5 | 4044.6 | 368.6 | 394.1 | 2161.4 | 20 |
| 22 | 3953.9 | 351.8 | 374.9 | 2106.3 | 4047.7 | 369.2 | 394.7 | 2163.3 | 22 |
| 24 | 3957.1 | 352.4 | 375.6 | 2108.2 | 4050.8 | 369.8 | 395.4 | 2165.2 | 24 |
| 26 | 3960.2 | 353.0 | 376.2 | 2110.1 | 4053.9 | 370.4 | 396.1 | 2167.1 | 26 |
| 28 | 3963.3 | 353.6 | 376.9 | 2112.0 | 4057.0 | 371.0 | 396.8 | 2169.0 | 28 |
| 30 | 3966.4 | 354.2 | 377.5 | 2113.9 | 4060.1 | 371.6 | 397.5 | 2170.9 | 30 |
| 32 | 3969.6 | 354.7 | 378.2 | 2115.8 | 4063.3 | 372.2 | 398.1 | 2172.8 | 32 |
| 34 | 3972.7 | 355.3 | 378.8 | 2117.7 | 4066.4 | 372.8 | 398.8 | 2174.7 | 34 |
| 36 | 3975.8 | 355.9 | 379.5 | 2119.6 | 4069.5 | 373.4 | 399.5 | 2176.6 | 36 |
| 38 | 3979.0 | 356.5 | 380.1 | 2121.5 | 4072.6 | 374.0 | 400.2 | 2178.5 | 38 |
| 40 | 3982.1 | 357.1 | 380.8 | 2123.4 | 4075.7 | 374.6 | 400.9 | 2180.4 | 40 |
| 42 | 3985.2 | 357.6 | 381.4 | 2125.3 | 4078.8 | 375.2 | 401.5 | 2182.4 | 42 |
| 44 | 3988.4 | 358.2 | 382.1 | 2127.2 | 4082.0 | 375.8 | 402.2 | 2184.3 | 44 |
| 46 | 3991.5 | 358.8 | 382.8 | 2129.1 | 4085.1 | 376.4 | 402.9 | 2186.2 | 46 |
| 48 | 3994.6 | 359.4 | 383.4 | 2131.0 | 4088.2 | 377.0 | 403.6 | 2188.1 | 48 |
| 50 | 3997.7 | 360.0 | 384.1 | 2132.9 | 4091.3 | 377.6 | 404.3 | 2190.0 | 50 |
| 52 | 4000.9 | 360.5 | 384.8 | 2134.7 | 4094.4 | 378.2 | 404.9 | 2191.9 | 52 |
| 54 | 4004.0 | 361.1 | 385.4 | 2136.6 | 4097.5 | 378.8 | 405.6 | 2193.8 | 54 |
| 56 | 4007.1 | 361.7 | 386.1 | 2138.5 | 4100.7 | 379.4 | 406.3 | 2195.7 | 56 |
| 58 | 4010.3 | 362.3 | 386.8 | 2140.4 | 4103.8 | 380.0 | 407.0 | 2197.6 | 58 |
| 60 | 4013.4 | 362.9 | 387.4 | 2142.3 | 4106.9 | 380.6 | 407.7 | 2199.5 | 60 |

| ′ | 42° | | | | 43° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 4106.9 | 380.6 | 407.7 | 2199.5 | 4200.1 | 398.7 | 428.6 | 2257.1 | 0 |
| 2 | 4110.0 | 381.2 | 408.3 | 2201.4 | 4203.2 | 399.3 | 429.3 | 2259.0 | 2 |
| 4 | 4113.1 | 381.8 | 409.0 | 2203.3 | 4206.3 | 399.9 | 430.0 | 2261.0 | 4 |
| 6 | 4116.2 | 382.4 | 409.7 | 2205.3 | 4209.4 | 400.5 | 430.7 | 2262.9 | 6 |
| 8 | 4119.3 | 383.0 | 410.4 | 2207.2 | 4212.5 | 401.1 | 431.4 | 2264.8 | 8 |
| 10 | 4122.4 | 383.6 | 411.1 | 2209.1 | 4215.6 | 401.7 | 432.1 | 2266.7 | 10 |
| 12 | 4125.5 | 384.2 | 411.8 | 2211.0 | 4218.7 | 402.4 | 432.8 | 2268.7 | 12 |
| 14 | 4128.6 | 384.8 | 412.5 | 2212.9 | 4221.8 | 403.0 | 433.5 | 2270.6 | 14 |
| 16 | 4131.8 | 385 4 | 413.2 | 2214.9 | 4224.9 | 403.6 | 434.2 | 2272.5 | 16 |
| 18 | 4134.9 | 386 0 | 413.9 | 2216.8 | 4228.0 | 404.2 | 434.9 | 2274.5 | 18 |
| 20 | 4138.0 | 386 3 | 414.6 | 2218.7 | 4231.1 | 404.8 | 435.6 | 2276.4 | 20 |
| 22 | 4141.1 | 387.2 | 415.3 | 2220.6 | 4234.2 | 405.4 | 436.3 | 2278.3 | 22 |
| 24 | 4144.2 | 387.8 | 416.0 | 2222.5 | 4237.3 | 406.1 | 437.0 | 2280.2 | 24 |
| 26 | 4147.3 | 388.4 | 416.6 | 2224.4 | 4240.4 | 406.7 | 437.8 | 2282.2 | 26 |
| 28 | 4150.4 | 389.0 | 417.3 | 2226.4 | 4243.5 | 407.3 | 438.5 | 2284.1 | 28 |
| 30 | 4153.5 | 389.6 | 418.0 | 2228.3 | 4246.5 | 407.9 | 439.2 | 2286.0 | 30 |
| 32 | 4156.6 | 390.2 | 418.7 | 2230.2 | 4249.6 | 408.5 | 439.9 | 2288.0 | 32 |
| 34 | 4159.7 | 390.8 | 419.4 | 2232.1 | 4252.7 | 409.1 | 440.6 | 2289.9 | 34 |
| 36 | 4162.8 | 391.4 | 420.1 | 2234.0 | 4255.8 | 409.8 | 441.4 | 2291.8 | 36 |
| 38 | 4165.9 | 392.0 | 420.8 | 2236.0 | 4258.9 | 410.4 | 442.1 | 2293.8 | 38 |
| 40 | 4169.0 | 392.6 | 421.5 | 2237.9 | 4262.0 | 411.0 | 442.8 | 2295.7 | 40 |
| 42 | 4172.1 | 393.2 | 422.2 | 2239.8 | 4265.1 | 411.6 | 443.5 | 2297.7 | 42 |
| 44 | 4175.2 | 393.8 | 422.9 | 2241.7 | 4268.2 | 412.2 | 444.2 | 2299.6 | 44 |
| 46 | 4178.4 | 394.4 | 423.6 | 2243.6 | 4271.3 | 412.8 | 445.0 | 2301.5 | 46 |
| 48 | 4181.5 | 395.0 | 424.3 | 2245.6 | 4274.4 | 413.5 | 445.7 | 2303.5 | 48 |
| 50 | 4184.6 | 395.6 | 425.0 | 2247.5 | 4277.5 | 414.1 | 446.4 | 2305.4 | 50 |
| 52 | 4187.7 | 396.2 | 425.7 | 2249.4 | 4280.6 | 414.7 | 447.1 | 2307.3 | 52 |
| 54 | 4190.8 | 396.8 | 426.4 | 2251.3 | 4283.7 | 415.3 | 447.8 | 2309.3 | 54 |
| 56 | 4193.9 | 397.4 | 427.1 | 2253.3 | 4286.8 | 415.9 | 448.6 | 2311.2 | 56 |
| 58 | 4197.0 | 398.0 | 427.8 | 2255.2 | 4289.9 | 416.5 | 449.3 | 2313.1 | 58 |
| 60 | 4200.1 | 398.7 | 428.6 | 2257.1 | 4293.0 | 417.2 | 450.0 | 2315.1 | 60 |

| ′ | 44° | | | | 45° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 4293.0 | 417.2 | 450.0 | 2315.1 | 4385.5 | 436.2 | 472.1 | 2373.4 | 0 |
| 2 | 4296.1 | 417.8 | 450.7 | 2317.0 | 4388.6 | 436.8 | 472.9 | 2375.4 | 2 |
| 4 | 4299.2 | 418.4 | 451.5 | 2319.0 | 4391.7 | 437.5 | 473.6 | 2377.3 | 4 |
| 6 | 4302.2 | 419.1 | 452.2 | 2320.9 | 4394.7 | 438.1 | 474.4 | 2379.3 | 6 |
| 8 | 4305.3 | 419.7 | 452.9 | 2322.8 | 4397.8 | 438.8 | 475.1 | 2381.2 | 8 |
| 10 | 4308.4 | 420.3 | 453.7 | 2324.8 | 4400.9 | 439.4 | 475.9 | 2383.2 | 10 |
| 12 | 4311.5 | 421.0 | 454.4 | 2326.7 | 4404.0 | 440.0 | 476.6 | 2385.2 | 12 |
| 14 | 4314.6 | 421.6 | 455.1 | 2328.7 | 4407.0 | 440.7 | 477.4 | 2387.1 | 14 |
| 16 | 4317.7 | 422.2 | 455.9 | 2330.6 | 4410.1 | 441.3 | 478.1 | 2389.1 | 16 |
| 18 | 4320.7 | 422.9 | 456.6 | 2332.6 | 4413.2 | 442.0 | 478.9 | 2391.0 | 18 |
| 20 | 4323.8 | 423.5 | 457.3 | 2334.5 | 4416.3 | 442.6 | 479.6 | 2393.0 | 20 |
| 22 | 4326.9 | 424.1 | 458.1 | 2336.4 | 4419.3 | 443.2 | 480.4 | 2394.9 | 22 |
| 24 | 4330.0 | 424.8 | 458.8 | 2338.4 | 4422.4 | 443.9 | 481.1 | 2396.9 | 24 |
| 26 | 4333.1 | 425.4 | 459.5 | 2340.3 | 4425.5 | 444.5 | 481.9 | 2398.8 | 26 |
| 28 | 4336.2 | 426.0 | 460.3 | 2342.3 | 4428.6 | 445.2 | 482.6 | 2400.8 | 28 |
| 30 | 4339.2 | 426.7 | 461.0 | 2344.2 | 4431.6 | 445.8 | 483.4 | 2402.8 | 30 |
| 32 | 4342.3 | 427.3 | 461.7 | 2346.1 | 4434.7 | 446.4 | 484.2 | 2404.7 | 32 |
| 34 | 4345.4 | 427.9 | 462.5 | 2348.1 | 4437.8 | 447.1 | 484.9 | 2406.7 | 34 |
| 36 | 4348.5 | 428.6 | 463.2 | 2350.0 | 4440.9 | 447.7 | 485.7 | 2408.6 | 36 |
| 38 | 4351.6 | 429.2 | 463.9 | 2352.0 | 4444.0 | 448.3 | 486.5 | 2410.6 | 38 |
| 40 | 4354.7 | 429.8 | 464.7 | 2353.9 | 4447.0 | 448.9 | 487.2 | 2412.6 | 40 |
| 42 | 4357.7 | 430.5 | 465.4 | 2355.9 | 4450.1 | 449.5 | 488.0 | 2414.5 | 42 |
| 44 | 4360.8 | 431.1 | 466.2 | 2357.8 | 4453.2 | 450.2 | 488.7 | 2416.5 | 44 |
| 46 | 4363.9 | 431.7 | 466.9 | 2359.8 | 4456.3 | 450.8 | 489.5 | 2418.5 | 46 |
| 48 | 4367.0 | 432.4 | 467.7 | 2361.7 | 4459.3 | 451.5 | 490.3 | 2420.4 | 48 |
| 50 | 4370.1 | 433.0 | 468 4 | 2363.7 | 4462.4 | 452.1 | 491.0 | 2422.4 | 50 |
| 52 | 4373.2 | 433.6 | 469.1 | 2365.6 | 4465.5 | 452.7 | 491.8 | 2424.4 | 52 |
| 54 | 4376.2 | 434.3 | 469.9 | 2367.6 | 4468.6 | 453.4 | 492.5 | 2426.3 | 54 |
| 56 | 4379.3 | 434.9 | 470.6 | 2369.5 | 4471.6 | 454.1 | 493.3 | 2428.3 | 56 |
| 58 | 4382.4 | 435.6 | 471.4 | 2371.5 | 4474.7 | 454.8 | 494.1 | 2430.2 | 58 |
| 60 | 4385.5 | 436.2 | 472.1 | 2373.4 | 4477.8 | 455.5 | 494.8 | 2432.2 | 60 |

[illegible] ONE DEGREE CURVE.

| ′ | 46° I. | M. | E. | T. | 47° I. | M. | E. | T. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 4 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 6 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 12 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 14 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 16 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 18 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 20 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 22 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 24 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 26 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 28 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 30 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2523.2 | 32 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2525.2 | 34 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 532.6 | 2527.2 | 36 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2529.2 | 38 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 534.2 | 2531.2 | 40 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2533.2 | 42 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2535.2 | 44 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 536.6 | 2537.2 | 46 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 537.4 | 2539.2 | 48 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 538.2 | 2541.2 | 50 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 539.0 | 2543.1 | 52 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2545.1 | 54 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 540.6 | 2547.1 | 56 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 541.4 | 2549.1 | 58 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 542.3 | 2551.1 | 60 |

| ′ | 48° I. | M. | E. | T. | 49° I. | M. | E. | T. | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 515.9 | 567.0 | 2611.3 | 0 |
| 2 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 567.8 | 2613.3 | 2 |
| 4 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 517.2 | [illegible] | 2615.3 | 4 |
| 6 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 517.9 | 569.5 | 2617.3 | 6 |
| 8 | [illegible] | [illegible] | [illegible] | [illegible] | 4764.4 | 518.6 | 570.3 | 2619.3 | 8 |
| 10 | [illegible] | [illegible] | [illegible] | [illegible] | 4767.4 | 519.3 | 571.2 | 2621.4 | 10 |
| 12 | [illegible] | [illegible] | [illegible] | [illegible] | 4770.5 | 520.0 | 572.0 | 2623.4 | 12 |
| 14 | [illegible] | [illegible] | [illegible] | [illegible] | 4773.5 | 520.7 | 572.8 | 2625.4 | 14 |
| 16 | [illegible] | [illegible] | [illegible] | [illegible] | 4776.5 | 521.4 | 573.7 | 2627.4 | 16 |
| 18 | 4688.5 | 501.5 | 549.6 | 2569.1 | 4779.6 | 522.1 | 574.5 | 2629.4 | 18 |
| 20 | 4691.6 | 502.2 | 550.5 | 2571.1 | 4782.6 | 522.8 | 575.3 | 2631.4 | 20 |
| 22 | 4694.6 | 502.8 | 551.3 | 2573.1 | 4785.6 | 523.5 | 576.2 | 2633.5 | 22 |
| 24 | 4697.6 | 503.5 | 552.1 | 2575.1 | 4788.7 | 524.2 | 577.0 | 2635.5 | 24 |
| 26 | 4700.7 | 504.2 | 552.9 | 2577.1 | 4791.7 | 524.9 | 577.9 | 2637.5 | 26 |
| 28 | 4703.7 | 504.9 | 553.7 | 2579.1 | 4794.7 | 525.6 | 578.7 | 2639.5 | 28 |
| 30 | 4706.7 | 505.6 | 554.6 | 2581.1 | 4797.7 | 526.3 | 579.6 | 2641.5 | 30 |
| 32 | 4709.8 | 506.2 | 555.4 | 2583.1 | 4800.8 | 527.0 | 580.4 | 2643.5 | 32 |
| 34 | 4712.8 | 506.9 | 556.2 | 2585.1 | 4803.8 | 527.7 | 581.3 | 2645.6 | 34 |
| 36 | 4715.9 | 507.6 | 557.0 | 2587.2 | 4806.8 | 528.4 | 582.1 | 2647.6 | 36 |
| 38 | 4718.9 | 508.3 | 557.8 | 2589.2 | 4809.9 | 529.1 | 583.0 | 2649.6 | 38 |
| 40 | 4721.9 | 509.0 | 558.7 | 2591.2 | 4812.9 | 529.8 | 583.8 | 2651.6 | 40 |
| 42 | 4725.0 | 509.6 | 559.5 | 2593.2 | 4815.9 | 530.5 | 584.7 | 2653.7 | 42 |
| 44 | 4728.0 | 510.3 | 560.3 | 2595.2 | 4819.0 | 531.2 | 585.5 | 2655.7 | 44 |
| 46 | 4731.0 | 511.0 | 561.2 | 2597.2 | 4822.0 | 531.9 | 586.4 | 2657.7 | 46 |
| 48 | 4734.1 | 511.7 | 562.0 | 2599.2 | 4825.0 | 532.6 | 587.2 | 2659.7 | 48 |
| 50 | 4737.1 | 512.4 | 562.8 | 2601.2 | 4828.0 | 533.3 | 588.1 | 2661.8 | 50 |
| 52 | 4740.2 | 513.1 | 563.7 | 2603.2 | 4831.1 | 534.0 | 588.9 | 2663.8 | 52 |
| 54 | 4743.2 | 513.8 | 564.5 | 2605.2 | 4834.1 | 534.7 | 589.8 | 2665.8 | 54 |
| 56 | 4746.2 | 514.5 | 565.3 | 2607.2 | 4837.1 | 535.4 | 590.6 | 2667.8 | 56 |
| 58 | 4749.3 | 515.2 | 566.2 | 2609.3 | 4840.2 | 536.1 | 591.5 | 2669.9 | 58 |
| 60 | 4752.3 | 515.9 | 567.0 | 2611.3 | 4843.2 | 536.8 | 592.4 | 2671.9 | 60 |

| ′ | 50° | | | | 51° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 4843.2 | 536.8 | 592.4 | 2671.9 | 4933 6 | 558.2 | 618.5 | 2733.0 | 0 |
| 2 | 4846.2 | 537.5 | 593.2 | 2673 9 | 4936.6 | 558.9 | 619.3 | 2735.1 | 2 |
| 4 | 4849.2 | 538.2 | 594.1 | 2676.0 | 4939.6 | 559.7 | 620.2 | 2737.1 | 4 |
| 6 | 4852.2 | 538.9 | 594.9 | 2678.0 | 4942.6 | 560.4 | 621.1 | 2739.2 | 6 |
| 8 | 4855.2 | 539.6 | 595.8 | 2680.0 | 4945.6 | 561.1 | 622.0 | 2741.2 | 8 |
| 10 | 4858.3 | 540.3 | 596.7 | 2682.1 | 4948.6 | 561.8 | 622.9 | 2743.3 | 10 |
| 12 | 4861.3 | 541.0 | 597.5 | 2684.1 | 4951.6 | 562.5 | 623.7 | 2745.3 | 12 |
| 14 | 4864.3 | 541.7 | 598.4 | 2686.1 | 4954.6 | 563.3 | 624.6 | 2747.4 | 14 |
| 16 | 4867.3 | 542.4 | 599.3 | 2688.2 | 4957.6 | 564.0 | 625.5 | 2749.4 | 16 |
| 18 | 4870.3 | 543.1 | 600.1 | 2690.2 | 4960.6 | 564.7 | 626.4 | 2751.5 | 18 |
| 20 | 4873.3 | 543.9 | 601.0 | 2692.3 | 4963.6 | 565.4 | 627.3 | 2753.5 | 20 |
| 22 | 4876.3 | 544.6 | 601.9 | 2694.3 | 4966.6 | 566.2 | 628.2 | 2755.6 | 22 |
| 24 | 4879.4 | 545.3 | 602.7 | 2696.3 | 4969.6 | 566.9 | 629.9 | 2757.7 | 24 |
| 26 | 4882.4 | 546.0 | 603.6 | 2698.4 | 4972.6 | 567.6 | 630.0 | 2759.7 | 26 |
| 28 | 4885.4 | 546.7 | 604.5 | 2700.4 | 4975.6 | 568.3 | 630.9 | 2761.8 | 28 |
| 30 | 4888.4 | 547.4 | 605.3 | 2702.4 | 4978.6 | 569.1 | 631.8 | 2763.8 | 30 |
| 32 | 4891.4 | 548.1 | 606.2 | 2704.5 | 4981.6 | 569.8 | 632.7 | 2765.9 | 32 |
| 34 | 4894.4 | 548.8 | 607.0 | 2706.5 | 4984.6 | 570.5 | 633.6 | 2767.9 | 34 |
| 36 | 4897.4 | 549.5 | 607.9 | 2708.6 | 4987.7 | 571.2 | 634.5 | 2770.0 | 36 |
| 38 | 4900.4 | 550.2 | 608.8 | 2710.6 | 4990.7 | 572.0 | 635.3 | 2772.0 | 38 |
| 40 | 4903.5 | 551.0 | 609.7 | 2712.6 | 4993.7 | 572.7 | 636.2 | 2774.1 | 40 |
| 42 | 4906.5 | 551.7 | 610.5 | 2714.7 | 4996.7 | 573.4 | 637.1 | 2776.2 | 42 |
| 44 | 4909.5 | 552.4 | 611.4 | 2716.7 | 4999.7 | 574.1 | 638.0 | 2778.2 | 44 |
| 46 | 4912.5 | 553.1 | 612.3 | 2718.8 | 5002.7 | 574.9 | 638.9 | 2780.3 | 46 |
| 48 | 4915.5 | 553.8 | 613.2 | 2720.8 | 5005.7 | 575.6 | 639.8 | 2782.3 | 48 |
| 50 | 4918.5 | 554.5 | 614.1 | 2722.8 | 5008.7 | 576.3 | 640.7 | 2784.4 | 50 |
| 52 | 4921.5 | 555.2 | 614.9 | 2724.9 | 5011.7 | 577.0 | 641.6 | 2786.4 | 52 |
| 54 | 4924.6 | 555.9 | 615.8 | 2726.9 | 5014.7 | 577.8 | 642.5 | 2788.5 | 54 |
| 56 | 4927.6 | 556.6 | 616.7 | 2729.0 | 5017.7 | 578.5 | 643.4 | 2790.6 | 56 |
| 58 | 4930.6 | 557.4 | 617.6 | 2731.0 | 5020.7 | 579.2 | 644.3 | 2792.6 | 58 |
| 60 | 4933.6 | 558.2 | 618.5 | 2733.0 | 5023.7 | 579.9 | 645.2 | 2794.7 | 60 |

| ′ | 52° | | | | 53° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 5023.7 | 579.9 | 645.2 | 2794.7 | 5113.5 | 602.0 | 672.7 | 2856.9 | 0 |
| 2 | 5026.7 | 580.6 | 646.1 | 2796.8 | 5116.5 | 602.8 | 673.7 | 2858.9 | 2 |
| 4 | 5029.7 | 581.3 | 647.0 | 2798.8 | 5119.4 | 603.5 | 674.6 | 2861.0 | 4 |
| 6 | 5032.7 | 582.1 | 647.9 | 2800.9 | 5122.4 | 604.3 | 675.5 | 2863.1 | 6 |
| 8 | 5035.7 | 582.8 | 648.9 | 2803.0 | 5125.4 | 605.0 | 676.4 | 2865.2 | 8 |
| 10 | 5038.7 | 583.5 | 649.8 | 2805.0 | 5128.4 | 605.8 | 677.4 | 2867.3 | 10 |
| 12 | 5041.7 | 584.3 | 650.7 | 2807.1 | 5131.3 | 606.5 | 678.3 | 2869.4 | 12 |
| 14 | 5044.7 | 585.0 | 651.6 | 2809.2 | 5134.3 | 607.3 | 679.2 | 2871.5 | 14 |
| 16 | 5047.7 | 585.7 | 652.5 | 2811.2 | 5137.3 | 608.0 | 680.2 | 2873.5 | 16 |
| 18 | 5050.7 | 586.5 | 653.4 | 2813.3 | 5140.3 | 608.8 | 681.1 | 2875.6 | 18 |
| 20 | 5053.6 | 587.2 | 654.3 | 2815.4 | 5143.2 | 609.5 | 682.0 | 2877.7 | 20 |
| 22 | 5056.6 | 587.9 | 655.2 | 2817.4 | 5146.2 | 610.3 | 683.0 | 2879.8 | 22 |
| 24 | 5059.6 | 588.7 | 656.2 | 2819.5 | 5149.2 | 611.0 | 683.9 | 2881.9 | 24 |
| 26 | 5062.6 | 589.4 | 657.1 | 2821.6 | 5152.1 | 611.8 | 684.9 | 2884.0 | 26 |
| 28 | 5065.6 | 590.1 | 658.0 | 2823.6 | 5155.1 | 612.5 | 685.8 | 2886.1 | 28 |
| 30 | 5068.6 | 590.9 | 658.9 | 2825.7 | 5158.1 | 613.3 | 686.7 | 2888.1 | 30 |
| 32 | 5071.6 | 591.6 | 659.8 | 2827.8 | 5161.1 | 614.0 | 687.7 | 2890.2 | 32 |
| 34 | 5074.6 | 592.3 | 660.7 | 2829.8 | 5164.0 | 614.8 | 688.6 | 2892.3 | 34 |
| 36 | 5077.6 | 593.1 | 661.6 | 2831.9 | 5167.0 | 615.5 | 689.6 | 2894.4 | 36 |
| 38 | 5080.6 | 593.8 | 662.5 | 2834.0 | 5170.0 | 616.3 | 690.5 | 2896.5 | 38 |
| 40 | 5083.6 | 594.5 | 663.5 | 2836.1 | 5173.0 | 617.0 | 691.5 | 2898.6 | 40 |
| 42 | 5086.6 | 595.3 | 664.4 | 2838.2 | 5175.9 | 617.8 | 692.4 | 2900.7 | 42 |
| 44 | 5089.6 | 596.0 | 665.3 | 2840.2 | 5178.9 | 618.5 | 693.4 | 2902.8 | 44 |
| 46 | 5092.6 | 596.7 | 666.2 | 2842.3 | 5181.9 | 619.3 | 694.3 | 2904.9 | 46 |
| 48 | 5095.6 | 597.5 | 667.2 | 2844.4 | 5184.9 | 620.1 | 695.3 | 2907.0 | 48 |
| 50 | 5098.6 | 598.2 | 668.1 | 2846.5 | 5187.8 | 620.8 | 696.2 | 2909.1 | 50 |
| 52 | 5101.6 | 598.9 | 669.0 | 2848.5 | 5190.8 | 621.5 | 697.1 | 2911.2 | 52 |
| 54 | 5104.6 | 599.7 | 669.9 | 2850.6 | 5193.8 | 622.3 | 698.1 | 2913.3 | 54 |
| 56 | 5107.6 | 600.4 | 670.9 | 2852.7 | 5196.7 | 623.0 | 699.0 | 2915.4 | 56 |
| 58 | 5110.6 | 601.2 | 671.8 | 2854.8 | 5199.7 | 623.8 | 700.0 | 2917.5 | 58 |
| 60 | 5113.5 | 602.0 | 672.7 | 2856.9 | 5202.7 | 624.6 | 700.9 | 2919.5 | 60 |

| ′ | 54° | | | | 55° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 5202.7 | 624.6 | 700.9 | 2919.5 | 5291.7 | 647.4 | 729.9 | 2982.8 | 0 |
| 2 | 5205.7 | 625.4 | 701.9 | 2921.6 | 5294.6 | 648.1 | 730.9 | 2984.9 | 2 |
| 4 | 5208.6 | 626.1 | 702.8 | 2923.8 | 5297.6 | 648.9 | 731.9 | 2987.1 | 4 |
| 6 | 5211.6 | 626.9 | 703.8 | 2925.9 | 5300.5 | 649.6 | 732.9 | 2989.2 | 6 |
| 8 | 5214.6 | 627.6 | 704.8 | 2928.0 | 5303.5 | 650.4 | 733.8 | 2991.3 | 8 |
| 10 | 5217.5 | 628.4 | 705.7 | 2930.1 | 5306.4 | 651.2 | 734.8 | 2993.4 | 10 |
| 12 | 5220.5 | 629.2 | 706.7 | 2932.2 | 5309.4 | 652.0 | 735.8 | 2995.5 | 12 |
| 14 | 5223.5 | 629.9 | 707.7 | 2934.3 | 5312.3 | 652.7 | 736.8 | 2997.7 | 14 |
| 16 | 5226.4 | 630.7 | 708.6 | 2936.4 | 5315.3 | 653.5 | 737.8 | 2999.8 | 16 |
| 18 | 5229.4 | 631.4 | 709.6 | 2938.5 | 5318.2 | 654.3 | 738.7 | 3001.9 | 18 |
| 20 | 5232.4 | 632.2 | 710.5 | 2940.6 | 5321.2 | 655.1 | 739.7 | 3004.0 | 20 |
| 22 | 5235.3 | 633.0 | 711.5 | 2942.7 | 5324.1 | 655.8 | 740.7 | 3006.2 | 22 |
| 24 | 5238.3 | 633.7 | 712.5 | 2944.8 | 5327.1 | 656.6 | 741.7 | 3008.3 | 24 |
| 26 | 5241.3 | 634.5 | 713.4 | 2946.9 | 5330.0 | 657.4 | 742.7 | 3010.4 | 26 |
| 28 | 5244.2 | 635.2 | 714.4 | 2949.0 | 5333.0 | 658.2 | 743.7 | 3012.5 | 28 |
| 30 | 5247.2 | 636.0 | 715.3 | 2951.1 | 5335.9 | 658.9 | 744.7 | 3014.7 | 30 |
| 32 | 5250.2 | 636.8 | 716.3 | 2953.2 | 5338.8 | 659.7 | 745.7 | 3016.8 | 32 |
| 34 | 5253.1 | 637.5 | 717.3 | 2955.3 | 5341.8 | 660.5 | 746.7 | 3018.9 | 34 |
| 36 | 5256.1 | 638.3 | 718.2 | 2957.5 | 5344.7 | 661.3 | 747.7 | 3021.1 | 36 |
| 38 | 5259.1 | 639.0 | 719.2 | 2959.6 | 5347.7 | 662.0 | 748.7 | 3023.2 | 38 |
| 40 | 5262.0 | 639.8 | 720.2 | 2961.7 | 5350.6 | 662.8 | 749.7 | 3025.3 | 40 |
| 42 | 5265.0 | 640.6 | 721.1 | 2963.8 | 5353.6 | 663.6 | 750.7 | 3027.5 | 42 |
| 44 | 5268.0 | 641.3 | 722.1 | 2965.9 | 5356.5 | 664.4 | 751.7 | 3029.6 | 44 |
| 46 | 5270.9 | 642.1 | 723.1 | 2968.0 | 5359.5 | 665.1 | 752.6 | 3031.7 | 46 |
| 48 | 5273.9 | 642.8 | 724.1 | 2970.1 | 5362.4 | 665.9 | 753.6 | 3033.8 | 48 |
| 50 | 5276.9 | 643.6 | 725.0 | 2972.2 | 5365.4 | 666.7 | 754.6 | 3036.0 | 50 |
| 52 | 5279.8 | 644.4 | 726.0 | 2974.4 | 5368.3 | 667.5 | 755.6 | 3038.1 | 52 |
| 54 | 5282.8 | 645.1 | 727.0 | 2976.5 | 5371.3 | 668.3 | 756.6 | 3040.2 | 54 |
| 56 | 5285.8 | 645.9 | 728.0 | 2978.6 | 5374.2 | 669.1 | 757.6 | 3042.4 | 56 |
| 58 | 5288.7 | 646.6 | 729.0 | 2980.7 | 5377.2 | 669.9 | 758.6 | 3044.5 | 58 |
| 60 | 5291.7 | 647.4 | 729.9 | 2982.8 | 5380.1 | 670.7 | 759.6 | 3046.6 | 60 |

| ′ | 56° | | | | 57° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 5380.1 | 670.7 | 759.6 | 3046.6 | 5468.2 | 694.4 | 790.2 | 3111.1 | 0 |
| 2 | 5383.0 | 671.4 | 760.6 | 3048.8 | 5471.1 | 695.2 | 791.2 | 3113.3 | 2 |
| 4 | 5386.0 | 672.2 | 761.6 | 3050.9 | 5474.0 | 696.0 | 792.2 | 3115.4 | 4 |
| 6 | 5388.9 | 672.9 | 762.7 | 3053.1 | 5477.0 | 696.8 | 793.3 | 3117.6 | 6 |
| 8 | 5391.8 | 673.7 | 763.7 | 3055.2 | 5479.9 | 697.6 | 794.3 | 3119.7 | 8 |
| 10 | 5394.8 | 674.4 | 764.7 | 3057.4 | 5482.8 | 698.4 | 795.3 | 3121.9 | 10 |
| 12 | 5397.7 | 675.2 | 765.7 | 3059.5 | 5485.7 | 699.2 | 796.3 | 3124.1 | 12 |
| 14 | 5400.7 | 676.0 | 766.7 | 3061.6 | 5488.7 | 700.0 | 797.4 | 3126.2 | 14 |
| 16 | 5403.6 | 676.8 | 767.7 | 3063.8 | 5491.6 | 700.8 | 798.4 | 3128.4 | 16 |
| 18 | 5406.5 | 677.6 | 768.7 | 3065.9 | 5494.5 | 701.6 | 799.4 | 3130.6 | 18 |
| 20 | 5409.5 | 678.4 | 769.7 | 3068.1 | 5497.4 | 702.4 | 800.5 | 3132.7 | 20 |
| 22 | 5412.4 | 679.2 | 770.8 | 3070.2 | 5500.3 | 703.2 | 801.5 | 3134.9 | 22 |
| 24 | 5415.3 | 680.0 | 771.8 | 3072.4 | 5503.3 | 704.0 | 802.6 | 3137.0 | 24 |
| 26 | 5418.3 | 680.8 | 772.8 | 3074.5 | 5506.2 | 704.8 | 803.6 | 3139.2 | 26 |
| 28 | 5421.2 | 681.6 | 773.8 | 3076.6 | 5509.1 | 705.6 | 804.7 | 3141.4 | 28 |
| 30 | 5424.1 | 682.4 | 774.8 | 3078.8 | 5512.0 | 706.4 | 805.7 | 3143.5 | 30 |
| 32 | 5427.1 | 683.2 | 775.8 | 3080.9 | 5515.0 | 707.2 | 806.8 | 3145.7 | 32 |
| 34 | 5430.0 | 684.0 | 776.8 | 3083.1 | 5517.9 | 708.0 | 807.8 | 3147.9 | 34 |
| 36 | 5433.0 | 684.8 | 777.8 | 3085.2 | 5520.8 | 708.8 | 808.8 | 3150.0 | 36 |
| 38 | 5435.9 | 685.6 | 778.9 | 3087.4 | 5523.7 | 709.6 | 809.9 | 3152.2 | 38 |
| 40 | 5438.8 | 686.4 | 779.9 | 3089.6 | 5526.7 | 710.4 | 810.9 | 3154.4 | 40 |
| 42 | 5441.8 | 687.2 | 780.9 | 3091.7 | 5529.6 | 711.2 | 812.0 | 3156.6 | 42 |
| 44 | 5444.7 | 688.0 | 781.9 | 3093.9 | 5532.5 | 712.0 | 813.0 | 3158.7 | 44 |
| 46 | 5447.6 | 688.8 | 783.0 | 3096.0 | 5535.4 | 712.8 | 814.1 | 3160.9 | 46 |
| 48 | 5450.6 | 689.6 | 784.0 | 3098.2 | 5538.4 | 713.6 | 815.1 | 3163.1 | 48 |
| 50 | 5453.5 | 690.4 | 785.0 | 3100.3 | 5541.3 | 714.4 | 816.2 | 3165.3 | 50 |
| 52 | 5456.5 | 691.2 | 786.0 | 3102.5 | 5544.2 | 715.2 | 817.2 | 3167.4 | 52 |
| 54 | 5459.4 | 692.0 | 787.1 | 3104.6 | 5547.1 | 716.0 | 818.3 | 3169.6 | 54 |
| 56 | 5462.3 | 692.8 | 788.1 | 3106.8 | 5550.0 | 716.8 | 819.3 | 3171.8 | 56 |
| 58 | 5465.3 | 693.6 | 789.1 | 3108.9 | 5553.0 | 717.6 | 820.4 | 3174.0 | 58 |
| 60 | 5468.2 | 694.4 | 790.2 | 3111.1 | 5555.9 | 718.4 | 821.4 | 3176.1 | 60 |

| ′ | 58° | | | | 59° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 5555.9 | 718.4 | 821.4 | 3176.1 | 5643.1 | 742.8 | 853.5 | 3241.9 | 0 |
| 2 | 5558.8 | 719.2 | 822.5 | 3178.3 | 5646.0 | 743.6 | 854.6 | 3244.1 | 2 |
| 4 | 5561.7 | 720.0 | 823.5 | 3180.5 | 5648.9 | 744.4 | 855.7 | 3246.3 | 4 |
| 6 | 5564.6 | 720.8 | 824.6 | 3182.7 | 5651.8 | 745.3 | 856.8 | 3248.5 | 6 |
| 8 | 5567.5 | 721.6 | 825.7 | 3184.9 | 5654.7 | 746.1 | 857.9 | 3250.7 | 8 |
| 10 | 5570.4 | 722.4 | 826.7 | 3187.1 | 5657.6 | 746.9 | 859.0 | 3252.9 | 10 |
| 12 | 5573.3 | 723.2 | 827.8 | 3189.2 | 5660.5 | 747.7 | 860.0 | 3255.1 | 12 |
| 14 | 5576.2 | 724.0 | 828.9 | 3191.4 | 5663.4 | 748.6 | 861.1 | 3257.3 | 14 |
| 16 | 5579.2 | 724.8 | 829.9 | 3193.6 | 5666.3 | 749.4 | 862.2 | 3259.5 | 16 |
| 18 | 5582.1 | 725.6 | 831.0 | 3195.8 | 5669.2 | 750.2 | 863.3 | 3261.7 | 18 |
| 20 | 5585.0 | 726.5 | 832.1 | 3198.0 | 5672.1 | 751.1 | 864.4 | 3263.9 | 20 |
| 22 | 5587.9 | 727.3 | 833.1 | 3200.2 | 5675.0 | 751.9 | 865.5 | 3266.1 | 22 |
| 24 | 5590.8 | 728.1 | 834.2 | 3202.4 | 5677.9 | 752.7 | 866.6 | 3268.3 | 24 |
| 26 | 5593.7 | 728.9 | 835.3 | 3204.5 | 5680.8 | 753.5 | 867.7 | 3270.5 | 26 |
| 28 | 5596.6 | 729.7 | 836.3 | 3206.7 | 5683.7 | 754.4 | 868.8 | 3272.7 | 28 |
| 30 | 5599.5 | 730.5 | 837.4 | 3208.9 | 5686.5 | 755.2 | 869.9 | 3274.9 | 30 |
| 32 | 5602.4 | 731.3 | 838.4 | 3211.1 | 5689.4 | 756.0 | 871.0 | 3277.1 | 32 |
| 34 | 5605.3 | 732.1 | 839.5 | 3213.3 | 5692.3 | 756.9 | 872.1 | 3279.4 | 34 |
| 36 | 5608.2 | 732.9 | 840.6 | 3215.5 | 5695.2 | 757.7 | 873.2 | 3281.6 | 36 |
| 38 | 5611.1 | 733.7 | 841.6 | 3217.7 | 5698.1 | 758.5 | 874.3 | 3283.8 | 38 |
| 40 | 5614.0 | 734.6 | 842.7 | 3219.9 | 5701.0 | 759.4 | 875.4 | 3286.0 | 40 |
| 42 | 5616.9 | 735.4 | 843.8 | 3222.1 | 5703.9 | 760.2 | 876.5 | 3288.2 | 42 |
| 44 | 5619.8 | 736.2 | 844.9 | 3224.3 | 5706.8 | 761.0 | 877.6 | 3290.5 | 44 |
| 46 | 5622.8 | 737.0 | 846.0 | 3226.5 | 5709.7 | 761.9 | 878.7 | 3292.7 | 46 |
| 48 | 5625.7 | 737.8 | 847.0 | 3228.7 | 5712.6 | 762.7 | 879.8 | 3294.9 | 48 |
| 50 | 5628.6 | 738.6 | 848.1 | 3230.9 | 5715.5 | 763.5 | 880.9 | 3297.1 | 50 |
| 52 | 5631.5 | 739.4 | 849.2 | 3233.1 | 5718.4 | 764.4 | 882.0 | 3299.3 | 52 |
| 54 | 5634.4 | 740.2 | 850.3 | 3235.3 | 5721.3 | 765.2 | 883.1 | 3301.5 | 54 |
| 56 | 5637.3 | 741.0 | 851.4 | 3237.5 | 5724.2 | 766.0 | 884.2 | 3303.8 | 56 |
| 58 | 5640.2 | 741.9 | 852.5 | 3239.7 | 5727.1 | 766.8 | 885.3 | 3306.0 | 58 |
| 60 | 5643.1 | 742.8 | 853.5 | 3241.9 | 5730.0 | 767.7 | 886.4 | 3308.2 | 60 |

| ′ | 60° | | | | 61° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M, | E. | T. | L. C. | M. | E. | T. | |
| 0 | 5730.0 | 767.7 | 886.4 | 3308.2 | 5816.4 | 792.9 | 920.2 | 3375.2 | 0 |
| 2 | 5732.9 | 768.5 | 887.5 | 3310.4 | 5819.3 | 793.7 | 921.4 | 3377.4 | 2 |
| 4 | 5735.8 | 769.4 | 888.7 | 3312.7 | 5822.1 | 794.6 | 922.5 | 3379.7 | 4 |
| 6 | 5738.6 | 770.2 | 889.8 | 3314.9 | 5825.0 | 795.4 | 923.6 | 3381.9 | 6 |
| 8 | 5741.5 | 771.1 | 890.9 | 3317.1 | 5827.9 | 796.3 | 924.8 | 3384.2 | 8 |
| 10 | 5744.4 | 771.9 | 892.0 | 3319.3 | 5830.7 | 797.1 | 925.9 | 3386.4 | 10 |
| 12 | 5747.3 | 772.7 | 893.1 | 3321.6 | 5833.6 | 798.0 | 927.1 | 3388.7 | 12 |
| 14 | 5750.2 | 773.6 | 894.3 | 3323.8 | 5836.5 | 798.8 | 928.2 | 3390.9 | 14 |
| 16 | 5753.0 | 774.4 | 895.4 | 3326.0 | 5839.3 | 799.7 | 929.3 | 3393.2 | 16 |
| 18 | 5755.9 | 775.3 | 896.5 | 3328.3 | 5842.2 | 800.5 | 930.5 | 3395.4 | 18 |
| 20 | 5758.8 | 776.1 | 897.6 | 3330.5 | 5845.1 | 801.4 | 931.6 | 3397.7 | 20 |
| 22 | 5761.7 | 776.9 | 898.8 | 3332.7 | 5847.9 | 802.2 | 932.8 | 3399.9 | 22 |
| 24 | 5764.6 | 777.8 | 899.9 | 3334.9 | 5850.8 | 803.1 | 933.9 | 3402.2 | 24 |
| 26 | 5767.4 | 778.6 | 901.0 | 3337.2 | 5853.7 | 803.9 | 935.1 | 3404.4 | 26 |
| 28 | 5770.3 | 779.5 | 902.1 | 3339.4 | 5856.5 | 804.8 | 936.3 | 3406.7 | 28 |
| 30 | 5773.2 | 780.3 | 903.2 | 3341.6 | 5859.4 | 805.6 | 937.4 | 3408.9 | 30 |
| 32 | 5776.1 | 781.1 | 904.4 | 3343.9 | 5862.3 | 806.5 | 938.6 | 3411.2 | 32 |
| 34 | 5779.0 | 782.0 | 905.5 | 3346.1 | 5865.1 | 807.3 | 939.7 | 3413.5 | 34 |
| 36 | 5781.8 | 782.8 | 906.6 | 3348.3 | 5868.0 | 808.2 | 940.9 | 3415.7 | 36 |
| 38 | 5784.7 | 783.7 | 907.7 | 3350.6 | 5870.9 | 809.0 | 942.1 | 3418.0 | 38 |
| 40 | 5787.6 | 784.5 | 908.8 | 3352.8 | 5873.7 | 809.9 | 943.2 | 3420.3 | 40 |
| 42 | 5790.5 | 785.3 | 910.0 | 3355.0 | 5876.6 | 810.7 | 944.4 | 3422.5 | 42 |
| 44 | 5793.4 | 786.2 | 911.1 | 3357.3 | 5879.5 | 811.6 | 945.5 | 3424.8 | 44 |
| 46 | 5796.2 | 787.0 | 912.3 | 3359.5 | 5882.3 | 812.4 | 946.7 | 3427.1 | 46 |
| 48 | 5799.1 | 787.9 | 913.4 | 3361.8 | 5885.2 | 813.3 | 947.8 | 3429.3 | 48 |
| 50 | 5802.0 | 788.7 | 914.5 | 3364.0 | 5888.1 | 814.1 | 949.0 | 3431.6 | 50 |
| 52 | 5804.9 | 789.5 | 915.7 | 3366.2 | 5890.9 | 815.0 | 950.2 | 3433.9 | 52 |
| 54 | 5807.8 | 790.4 | 916.8 | 3368.5 | 5893.8 | 815.8 | 951.3 | 3436.1 | 54 |
| 56 | 5810.6 | 791.2 | 918.0 | 3370.7 | 5896.7 | 816.7 | 952.5 | 3438.4 | 56 |
| 58 | 5813.5 | 792.1 | 919.1 | 3373.0 | 5899.5 | 817.5 | 953.6 | 3440.7 | 58 |
| 60 | 5816.4 | 792.9 | 920.2 | 3375.2 | 5902.4 | 818.4 | 954.8 | 3442.9 | 60 |

| ′ | 62° | | | | 63° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 5902.4 | 818.4 | 954.8 | 3442.9 | 5987.8 | 844.4 | 990.3 | 3511.3 | 0 |
| 2 | 5905.2 | 819.3 | 956.0 | 3445.2 | 5990.6 | 845.3 | 991.5 | 3513.6 | 2 |
| 4 | 5908.1 | 820.1 | 957.2 | 3447.5 | 5993.5 | 846.2 | 992.7 | 3515.9 | 4 |
| 6 | 5910.9 | 821.0 | 958.3 | 3449.7 | 5996.3 | 847.1 | 993.9 | 3518.2 | 6 |
| 8 | 5913.8 | 821.8 | 959.5 | 3452.0 | 5999.1 | 847.9 | 995.1 | 3520.5 | 8 |
| 10 | 5916.6 | 822.7 | 960.7 | 3454.3 | 6002.0 | 848.8 | 996.3 | 3522.8 | 10 |
| 12 | 5919.5 | 823.6 | 961.9 | 3456.6 | 6004.8 | 849.7 | 997.5 | 3525.1 | 12 |
| 14 | 5922.3 | 824.4 | 963.0 | 3458.8 | 6007.7 | 850.6 | 998.7 | 3527.4 | 14 |
| 16 | 5925.2 | 825.3 | 964.2 | 3461.1 | 6010.5 | 851.4 | 999.9 | 3529.7 | 16 |
| 18 | 5928.0 | 826.1 | 965.4 | 3463.4 | 6013.3 | 852.3 | 1001.1 | 3532.0 | 18 |
| 20 | 5930.9 | 827.0 | 966.6 | 3465.7 | 6016.2 | 853.2 | 1002.3 | 3534.3 | 20 |
| 22 | 5933.7 | 827.9 | 967.8 | 3467.9 | 6019.0 | 854.1 | 1003.5 | 3536.6 | 22 |
| 24 | 5936.6 | 828.7 | 968.9 | 3470.2 | 6021.8 | 854.9 | 1004.7 | 3538.9 | 24 |
| 26 | 5939.4 | 829.6 | 970.1 | 3472.5 | 6024.7 | 855.8 | 1005.9 | 3541.2 | 26 |
| 28 | 5942.3 | 830.4 | 971.3 | 3474.7 | 6027.5 | 856.7 | 1007.1 | 3543.5 | 28 |
| 30 | 5945.1 | 831.3 | 972.5 | 3477.0 | 6030.3 | 857.6 | 1008.4 | 3545.8 | 30 |
| 32 | 5947.9 | 832.2 | 973.6 | 3479.3 | 6033.2 | 858.4 | 1009.6 | 3548.1 | 32 |
| 34 | 5950.8 | 833.0 | 974.8 | 3481.6 | 6036.0 | 859.3 | 1010.8 | 3550.4 | 34 |
| 36 | 5953.6 | 833.9 | 976.0 | 3483.9 | 6038.9 | 860.2 | 1012.0 | 3552.7 | 36 |
| 38 | 5956.5 | 834.7 | 977.2 | 3486.2 | 6041.7 | 861.1 | 1013.2 | 3555.0 | 38 |
| 40 | 5959.3 | 835.6 | 978.4 | 3488.5 | 6044.5 | 861.9 | 1014.5 | 3557.3 | 40 |
| 42 | 5962.2 | 836.5 | 979.6 | 3490.7 | 6047.4 | 862.8 | 1015.7 | 3559.6 | 42 |
| 44 | 5965.0 | 837.4 | 980.8 | 3493.0 | 6050.2 | 863.7 | 1016.9 | 3562.0 | 44 |
| 46 | 5967.9 | 838.3 | 982.0 | 3495.3 | 6053.0 | 864.6 | 1018.1 | 3564.3 | 46 |
| 48 | 5970.7 | 839.1 | 983.2 | 3497.6 | 6055.9 | 865.4 | 1019.3 | 3566.6 | 48 |
| 50 | 5973.6 | 840.0 | 984.4 | 3499.9 | 6058.7 | 866.3 | 1020.6 | 3568.9 | 50 |
| 52 | 5976.4 | 840.9 | 985.5 | 3502.2 | 6061.6 | 867.2 | 1021.8 | 3571.2 | 52 |
| 54 | 5979.3 | 841.7 | 986.7 | 3504.5 | 6064.4 | 868.1 | 1023.0 | 3573.5 | 54 |
| 56 | 5982.1 | 842.6 | 987.9 | 3506.8 | 6067.2 | 868.9 | 1024.2 | 3575.8 | 56 |
| 58 | 5985.0 | 843.5 | 989.1 | 3509.0 | 6070.1 | 869.8 | 1025.4 | 3578.1 | 58 |
| 60 | 5987.8 | 844.4 | 990.3 | 3511.3 | 6072.9 | 870.7 | 1026.7 | 3580.4 | 60 |

| ′ | 64° | | | | 65° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 6072.9 | 870.7 | 1026.7 | 3580.4 | 6157.5 | 897.3 | 1064.0 | 3650.4 | 0 |
| 2 | 6075.7 | 871.5 | 1027.9 | 3582.8 | 6160.3 | 898.2 | 1065.2 | 3652.8 | 2 |
| 4 | 6078.5 | 872.4 | 1029.2 | 3585.1 | 6163.1 | 899.1 | 1066.5 | 3655.1 | 4 |
| 6 | 6081.4 | 873.3 | 1030.4 | 3587.4 | 6165.9 | 900.0 | 1067.7 | 3657.5 | 6 |
| 8 | 6084.2 | 874.2 | 1031.7 | 3589.7 | 6168.7 | 900.9 | 1069.0 | 3659.8 | 8 |
| 10 | 6087.0 | 875.1 | 1032.9 | 3592.1 | 6171.5 | 901.8 | 1070.2 | 3662.2 | 10 |
| 12 | 6089.8 | 875.9 | 1034.1 | 3594.4 | 6174.3 | 902.7 | 1071.5 | 3664.5 | 12 |
| 14 | 6092.6 | 876.8 | 1035.4 | 3596.7 | 6177.1 | 903.6 | 1072.7 | 3666.9 | 14 |
| 16 | 6095.5 | 877.7 | 1036.6 | 3599.1 | 6179.9 | 904.5 | 1074.0 | 3669.2 | 16 |
| 18 | 6098.3 | 878.6 | 1037.9 | 3601.4 | 6182.7 | 905.4 | 1075.2 | 3671.6 | 18 |
| 20 | 6101.1 | 879.5 | 1039.1 | 3603.7 | 6185.5 | 906.3 | 1076.6 | 3673.9 | 20 |
| 22 | 6103.9 | 880.3 | 1040.3 | 3606.0 | 6188.3 | 907.2 | 1077.8 | 3676.2 | 22 |
| 24 | 6106.7 | 881.2 | 1041.6 | 3608.4 | 6191.1 | 908.1 | 1079.1 | 3678.6 | 24 |
| 26 | 6109.6 | 882.1 | 1042.8 | 3610.7 | 6193.9 | 909.0 | 1080.4 | 3680.9 | 26 |
| 28 | 6112.4 | 883.0 | 1044.1 | 3613.0 | 6196.7 | 909.9 | 1081.7 | 3683.3 | 28 |
| 30 | 6115.2 | 883.9 | 1045.3 | 3615.3 | 6199.5 | 910.8 | 1083.0 | 3685.6 | 30 |
| 32 | 6118.0 | 884.7 | 1046.5 | 3617.7 | 6202.3 | 911.7 | 1084.2 | 3688.0 | 32 |
| 34 | 6120.8 | 885.6 | 1047.8 | 3620.0 | 6205.1 | 912.6 | 1085.5 | 3690.4 | 34 |
| 36 | 6123.7 | 886.5 | 1049.0 | 3622.3 | 6208.0 | 913.5 | 1086.8 | 3692.7 | 36 |
| 38 | 6126.5 | 887.4 | 1050.3 | 3624.7 | 6210.8 | 914.4 | 1088.1 | 3695.1 | 38 |
| 40 | 6129.3 | 888.3 | 1051.5 | 3627.0 | 6213.6 | 915.3 | 1089.4 | 3697.4 | 40 |
| 42 | 6132.1 | 889.2 | 1052.7 | 3629.4 | 6216.4 | 916.2 | 1090.6 | 3699.8 | 42 |
| 44 | 6134.9 | 890.1 | 1054.0 | 3631.7 | 6219.2 | 917.1 | 1091.9 | 3702.2 | 44 |
| 46 | 6137.8 | 891.0 | 1055.2 | 3634.0 | 6222.0 | 918.0 | 1093.2 | 3704.5 | 46 |
| 48 | 6140.6 | 891.9 | 1056.5 | 3636.4 | 6224.8 | 918.9 | 1094.5 | 3706.9 | 48 |
| 50 | 6143.4 | 892.8 | 1057.7 | 3638.7 | 6227.6 | 919.8 | 1095.8 | 3709.3 | 50 |
| 52 | 6146.2 | 893.7 | 1059.0 | 3641.1 | 6230.4 | 920.7 | 1097.0 | 3711.6 | 52 |
| 54 | 6149.0 | 894.6 | 1060.2 | 3643.4 | 6233.2 | 921.6 | 1098.3 | 3714.0 | 54 |
| 56 | 6151.9 | 895.5 | 1061.5 | 3645.7 | 6236.0 | 922.5 | 1099.6 | 3716.3 | 56 |
| 58 | 6154.7 | 896.4 | 1062.7 | 3648.1 | 6238.8 | 923.4 | 1100.9 | 3718.7 | 58 |
| 60 | 6157.5 | 897.3 | 1064.0 | 3650.4 | 6241.6 | 924.3 | 1102.2 | 3721.1 | 60 |

| ′ | 66° | | | | 67° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 6241.6 | 924.3 | 1102.2 | 3721.1 | 6325.2 | 951.8 | 1141.5 | 3792.6 | 0 |
| 2 | 6244.4 | 925.2 | 1103.5 | 3723.4 | 6328.0 | 952.7 | 1142.8 | 3795.0 | 2 |
| 4 | 6247.2 | 926.1 | 1104.8 | 3725.8 | 6330.7 | 953.6 | 1144.1 | 3797.4 | 4 |
| 6 | 6250.0 | 927.0 | 1106.1 | 3728.2 | 6333.5 | 954.5 | 1145.4 | 3799.8 | 6 |
| 8 | 6252.7 | 927.9 | 1107.4 | 3730.6 | 6336.3 | 955.5 | 1146.7 | 3802.2 | 8 |
| 10 | 6255.5 | 928.8 | 1108.7 | 3732.9 | 6339.0 | 956.4 | 1148.1 | 3804.6 | 10 |
| 12 | 6258.3 | 929.8 | 1110.0 | 3735.3 | 6341.8 | 957.3 | 1149.4 | 3807.0 | 12 |
| 14 | 6261.1 | 930.7 | 1111.3 | 3737.7 | 6344.6 | 958.2 | 1150.7 | 3809.4 | 14 |
| 16 | 6263.9 | 931.6 | 1112.6 | 3740.1 | 6347.4 | 959.2 | 1152.0 | 3811.8 | 16 |
| 18 | 6266.7 | 932.5 | 1113.9 | 3742.4 | 6350.1 | 960.1 | 1153.3 | 3814.2 | 18 |
| 20 | 6269.5 | 933.4 | 1115.2 | 3744.8 | 6352.9 | 961.0 | 1154.7 | 3816.6 | 20 |
| 22 | 6272.3 | 934.3 | 1116.5 | 3747.2 | 6355.7 | 961.9 | 1156.0 | 3819.0 | 22 |
| 24 | 6275.0 | 935.3 | 1117.8 | 3749.6 | 6358.4 | 962.9 | 1157.4 | 3821.4 | 24 |
| 26 | 6277.8 | 936.2 | 1119.1 | 3751.9 | 6361.2 | 963.8 | 1158.7 | 3823.8 | 26 |
| 28 | 6280.6 | 937.1 | 1120.4 | 3754.3 | 6364.0 | 964.7 | 1160.1 | 3826.2 | 28 |
| 30 | 6283.4 | 938.0 | 1121.7 | 3756.7 | 6366.7 | 965.6 | 1161.4 | 3828.6 | 30 |
| 32 | 6286.2 | 938.9 | 1123.0 | 3759.1 | 6369.5 | 966.6 | 1162.8 | 3831.0 | 32 |
| 34 | 6289.0 | 939.8 | 1124.3 | 3761.5 | 6372.3 | 967.5 | 1164.1 | 3833.4 | 34 |
| 36 | 6291.8 | 940.8 | 1125.6 | 3763.9 | 6375.1 | 968.4 | 1165.5 | 3835.9 | 36 |
| 38 | 6294.5 | 941.7 | 1126.9 | 3766.3 | 6377.8 | 969.3 | 1166.8 | 3838.3 | 38 |
| 40 | 6297.3 | 942.6 | 1128.3 | 3768.7 | 6380.6 | 970.3 | 1168.2 | 3840.7 | 40 |
| 42 | 6300.1 | 943.5 | 1129.6 | 3771.0 | 6383.4 | 971.2 | 1169.5 | 3843.1 | 42 |
| 44 | 6302.9 | 944.4 | 1130.9 | 3773.4 | 6386.1 | 972.1 | 1170.9 | 3845.5 | 44 |
| 46 | 6305.7 | 945.3 | 1132.2 | 3775.8 | 6388.9 | 973.0 | 1172.2 | 3847.9 | 46 |
| 48 | 6308.5 | 946.3 | 1133.5 | 3778.2 | 6391.7 | 974.0 | 1173.6 | 3850.4 | 48 |
| 50 | 6311.3 | 947.2 | 1134.9 | 3780.6 | 6394.4 | 974.9 | 1174.9 | 3852.8 | 50 |
| 52 | 6314.1 | 948.1 | 1136.2 | 3783.0 | 6397.2 | 975.8 | 1176.3 | 3855.2 | 52 |
| 54 | 6316.8 | 949.0 | 1137.5 | 3785.4 | 6400.0 | 976.8 | 1177.6 | 3857.6 | 54 |
| 56 | 6319.6 | 949.9 | 1138.8 | 3787.8 | 6402.8 | 977.7 | 1179.0 | 3860.0 | 56 |
| 58 | 6322.4 | 950.8 | 1140.1 | 3790.2 | 6405.5 | 978.6 | 1180.3 | 3862.5 | 58 |
| 60 | 6325.2 | 951.8 | 1141.5 | 3792.6 | 6408.3 | 979.6 | 1181.6 | 3864.9 | 60 |

| ′ | 68° | | | | 69° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 6408.3 | 979.6 | 1181.6 | 3864.9 | 6491.1 | 1007.7 | 1222.9 | 3938.1 | 0 |
| 2 | 6411.1 | 980.5 | 1183.0 | 3867.3 | 6493.8 | 1008.7 | 1224.3 | 3940.6 | 2 |
| 4 | 6413.8 | 981.4 | 1184.4 | 3869.7 | 6496.6 | 1009.6 | 1225.7 | 3943.0 | 4 |
| 6 | 6416.6 | 982.4 | 1185.7 | 3872.2 | 6499.3 | 1010.6 | 1227.1 | 3945.5 | 6 |
| 8 | 6419.3 | 983.3 | 1187.1 | 3874.6 | 6502.1 | 1011.5 | 1228.5 | 3947.9 | 8 |
| 10 | 6422.1 | 984.2 | 1188.5 | 3877.0 | 6504.8 | 1012.5 | 1229.9 | 3950.4 | 10 |
| 12 | 6421.9 | 985.2 | 1189.8 | 3879.5 | 6507.5 | 1013.4 | 1231.3 | 3952.9 | 12 |
| 14 | 6427.6 | 986.1 | 1191.2 | 3881.9 | 6510.3 | 1014.4 | 1232.7 | 3955.3 | 14 |
| 16 | 6430.4 | 987.0 | 1192.6 | 3884.3 | 6513.0 | 1015.3 | 1234.1 | 3957.8 | 16 |
| 18 | 6433.1 | 988.0 | 1193.9 | 3886.8 | 6515.8 | 1016.3 | 1235.5 | 3960.2 | 18 |
| 20 | 6435.9 | 988.9 | 1195.3 | 3889.2 | 6518.5 | 1017.2 | 1236.9 | 3962.7 | 20 |
| 22 | 6438.7 | 989.8 | 1196.7 | 3891.6 | 6521.2 | 1018.2 | 1238.3 | 3965.2 | 22 |
| 24 | 6441.4 | 990.8 | 1198.0 | 3894.1 | 6524.0 | 1019.1 | 1239.7 | 3967.6 | 24 |
| 26 | 6444.2 | 991.7 | 1199.4 | 3896.5 | 6526.7 | 1020.1 | 1241.1 | 3970.1 | 26 |
| 28 | 6446.9 | 992.6 | 1200.8 | 3898.9 | 6529.5 | 1021.0 | 1242.5 | 3972.5 | 28 |
| 30 | 6449.7 | 993.6 | 1202.1 | 3901.4 | 6532.2 | 1022.0 | 1243.9 | 3975.0 | 30 |
| 32 | 6452.5 | 994.5 | 1203.5 | 3903.8 | 6534.9 | 1022.9 | 1245.3 | 3977.5 | 32 |
| 34 | 6455.2 | 995.4 | 1204.9 | 3906.3 | 6537.7 | 1023.9 | 1246.7 | 3980.0 | 34 |
| 36 | 6458.0 | 996.4 | 1206.2 | 3908.7 | 6540.4 | 1024.8 | 1248.1 | 3982.4 | 36 |
| 38 | 6460.7 | 997.3 | 1207.6 | 3911.2 | 6543.2 | 1025.8 | 1249.5 | 3984.9 | 38 |
| 40 | 6463.5 | 998.2 | 1209.0 | 3913.6 | 6545.9 | 1026.7 | 1250.9 | 3987.4 | 40 |
| 42 | 6466.3 | 999.2 | 1210.3 | 3916.1 | 6548.6 | 1027.7 | 1252.3 | 3989.9 | 42 |
| 44 | 6469.0 | 1000.1 | 1211.7 | 3918.5 | 6551.4 | 1028.6 | 1253.7 | 3992.3 | 44 |
| 46 | 6471.8 | 1001.0 | 1213.1 | 3921.0 | 6554.1 | 1029.6 | 1255.1 | 3994.8 | 46 |
| 48 | 6474.5 | 1002.0 | 1214.5 | 3923.4 | 6556.9 | 1030.5 | 1256.5 | 3997.3 | 48 |
| 50 | 6477.3 | 1002.9 | 1215.9 | 3925.9 | 6559.6 | 1031.5 | 1257.9 | 3999.8 | 50 |
| 52 | 6480.1 | 1003.8 | 1217.3 | 3928.3 | 6562.3 | 1032.4 | 1259.3 | 4002.2 | 52 |
| 54 | 6482.8 | 1004.8 | 1218.7 | 3930.8 | 6565.1 | 1033.4 | 1260.7 | 4004.7 | 54 |
| 56 | 6485.6 | 1005.7 | 1220.1 | 3933.2 | 6567.8 | 1034.3 | 1262.1 | 4007.2 | 56 |
| 58 | 6488.3 | 1006.7 | 1221.5 | 3935.7 | 6570.6 | 1035.3 | 1263.5 | 4009.7 | 58 |
| 60 | 6491.1 | 1007.7 | 1222.9 | 3938.1 | 6573.3 | 1036.3 | 1265.0 | 4012.1 | 60 |

| ′ | 70° | | | | 71° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 6573.3 | 1036.3 | 1265.0 | 4012.1 | 6654.9 | 1065.1 | 1308.4 | 4087.1 | 0 |
| 2 | 6576.0 | 1037.3 | 1266.4 | 4014.6 | 6657.6 | 1066.1 | 1309.9 | 4089.7 | 2 |
| 4 | 6578.7 | 1038.2 | 1267.9 | 4017.1 | 6660.3 | 1067.0 | 1311.3 | 4092.2 | 4 |
| 6 | 6581.5 | 1039.2 | 1269.3 | 4019.6 | 6663.0 | 1068.0 | 1312.8 | 4094.7 | 6 |
| 8 | 6584.2 | 1040.1 | 1270.8 | 4022.1 | 6665.7 | 1068.9 | 1314.2 | 4097.2 | 8 |
| 10 | 6586.9 | 1041.1 | 1272.2 | 4024.6 | 6668.4 | 1069.9 | 1315.7 | 4099.8 | 10 |
| 12 | 6589.6 | 1042.1 | 1273.6 | 4027.1 | 6671.1 | 1070.9 | 1317.2 | 4102.3 | 12 |
| 14 | 6592.3 | 1043.0 | 1275.1 | 4029.6 | 6673.8 | 1071.9 | 1318.6 | 4104.8 | 14 |
| 16 | 6595.1 | 1044.0 | 1276.5 | 4032.1 | 6676.6 | 1072.9 | 1320.1 | 4107.3 | 16 |
| 18 | 6597.8 | 1044.9 | 1278.0 | 4034.6 | 6679.3 | 1073.8 | 1321.5 | 4109.8 | 18 |
| 20 | 6600.5 | 1045.9 | 1279.4 | 4037.1 | 6682.0 | 1074.8 | 1323.0 | 4112.4 | 20 |
| 22 | 6603.2 | 1046.9 | 1280.8 | 4039.6 | 6684.7 | 1075.8 | 1324.4 | 4114.9 | 22 |
| 24 | 6605.9 | 1047.8 | 1282.3 | 4042.1 | 6687.4 | 1076.8 | 1325.9 | 4117.4 | 24 |
| 26 | 6608.7 | 1048.8 | 1283.7 | 4044.6 | 6690.1 | 1077.7 | 1327.4 | 4119.9 | 26 |
| 28 | 6611.4 | 1049.7 | 1285.2 | 4047.1 | 6692.8 | 1078.7 | 1328.9 | 4122.4 | 28 |
| 30 | 6614.1 | 1050.7 | 1286.6 | 4049.6 | 6695.5 | 1079.7 | 1330.4 | 4125.0 | 30 |
| 32 | 6616.8 | 1051.7 | 1288.0 | 4052.1 | 6698.2 | 1080.7 | 1331.8 | 4127.5 | 32 |
| 34 | 6619.5 | 1052.6 | 1289.5 | 4054.6 | 6700.9 | 1081.6 | 1333.3 | 4130.1 | 34 |
| 36 | 6622.3 | 1053.6 | 1290.9 | 4057.1 | 6703.6 | 1082.6 | 1334.8 | 4132.6 | 36 |
| 38 | 6625.0 | 1054.5 | 1292.4 | 4059.6 | 6706.3 | 1083.6 | 1336.3 | 4135.1 | 38 |
| 40 | 6627.7 | 1055.5 | 1293.8 | 4062.1 | 6709.0 | 1084.5 | 1337.8 | 4137.7 | 40 |
| 42 | 6630.4 | 1056.5 | 1295.3 | 4064.6 | 6711.7 | 1085.5 | 1339.2 | 4140.2 | 42 |
| 44 | 6633.1 | 1057.4 | 1296.7 | 4067.1 | 6714.4 | 1086.5 | 1340.7 | 4142.7 | 44 |
| 46 | 6635.9 | 1058.4 | 1298.2 | 4069.6 | 6717.2 | 1087.5 | 1342.2 | 4145.3 | 46 |
| 48 | 6638.6 | 1059.3 | 1299.6 | 4072.1 | 6719.9 | 1088.4 | 1343.7 | 4147.8 | 48 |
| 50 | 6641.3 | 1060.3 | 1301.1 | 4074.6 | 6722.6 | 1089.4 | 1345.2 | 4150.4 | 50 |
| 52 | 6644.0 | 1061.3 | 1302.6 | 4077.1 | 6725.3 | 1090.4 | 1346.7 | 4152.9 | 52 |
| 54 | 6646.7 | 1062.2 | 1304.0 | 4079.6 | 6728.0 | 1091.3 | 1348.2 | 4155.4 | 54 |
| 56 | 6649.5 | 1063.2 | 1305.5 | 4082.1 | 6730.7 | 1092.3 | 1349.7 | 4158.0 | 56 |
| 58 | 6652.2 | 1064.1 | 1306.9 | 4084.6 | 6733.4 | 1093.3 | 1351.2 | 4160.5 | 58 |
| 60 | 6654.9 | 1065.1 | 1308.4 | 4087.1 | 6736.1 | 1094.3 | 1352.7 | 4163.1 | 60 |

| ′ | 72° | | | | 73° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 6736.1 | 1094.3 | 1352.7 | 4163.1 | 6816.6 | 1123.9 | 1398.1 | 4240.0 | 0 |
| 2 | 6738.8 | 1095.2 | 1354.2 | 4165.6 | 6819.3 | 1124.8 | 1399.6 | 4242.6 | 2 |
| 4 | 6741.5 | 1096.2 | 1355.7 | 4168.2 | 6821.9 | 1125.8 | 1401.2 | 4245.1 | 4 |
| 6 | 6744.1 | 1097.2 | 1357.2 | 4170.7 | 6824.6 | 1126.8 | 1402.7 | 4247.7 | 6 |
| 8 | 6746.8 | 1098.2 | 1358.7 | 4173.3 | 6827.3 | 1127.8 | 1404.2 | 4250.3 | 8 |
| 10 | 6749.5 | 1099.2 | 1360.2 | 4175.8 | 6830.0 | 1128.8 | 1405.8 | 4252.9 | 10 |
| 12 | 6752.2 | 1100.1 | 1361.7 | 4178.4 | 6832.6 | 1129.8 | 1407.3 | 4255.5 | 12 |
| 14 | 6754.9 | 1101.1 | 1363.2 | 4181.0 | 6835.3 | 1130.8 | 1408.8 | 4258.1 | 14 |
| 16 | 6757.6 | 1102.1 | 1364.7 | 4183.5 | 6838.0 | 1131.8 | 1410.4 | 4260.7 | 16 |
| 18 | 6760.2 | 1103.1 | 1366.2 | 4186.1 | 6840.7 | 1132.8 | 1411.9 | 4263.2 | 18 |
| 20 | 6762.9 | 1104.1 | 1367.7 | 4188.6 | 6843.3 | 1133.8 | 1413.5 | 4265.8 | 20 |
| 22 | 6765.6 | 1105.1 | 1369.2 | 4191.2 | 6846.0 | 1134.8 | 1415.1 | 4268.4 | 22 |
| 24 | 6768.3 | 1106.0 | 1370.7 | 4193.7 | 6848.7 | 1135.8 | 1416.6 | 4271.0 | 24 |
| 26 | 6771.0 | 1107.0 | 1372.2 | 4196.3 | 6851.3 | 1136.8 | 1418.2 | 4273.6 | 26 |
| 28 | 6773.7 | 1108.0 | 1373.7 | 4198.8 | 6854.0 | 1137.8 | 1419.7 | 4276.2 | 28 |
| 30 | 6776.3 | 1109.0 | 1375.2 | 4201.4 | 6856.7 | 1138.8 | 1421.3 | 4278.8 | 30 |
| 32 | 6779.0 | 1109.9 | 1376.7 | 4204.0 | 6859.4 | 1139.8 | 1422.9 | 4281.4 | 32 |
| 34 | 6781.7 | 1110.9 | 1378.2 | 4206.5 | 6862.0 | 1140.8 | 1424.4 | 4284.0 | 34 |
| 36 | 6784.4 | 1111.9 | 1379.7 | 4209.1 | 6864.7 | 1141.8 | 1426.0 | 4286.6 | 36 |
| 38 | 6787.1 | 1112.9 | 1381.2 | 4211.7 | 6867.4 | 1142.8 | 1427.5 | 4289.2 | 38 |
| 40 | 6789.8 | 1113.9 | 1382.8 | 4214.3 | 6870.1 | 1143.8 | 1429.1 | 4291.8 | 40 |
| 42 | 6792.4 | 1114.9 | 1384.3 | 4216.8 | 6872.7 | 1144.8 | 1430.7 | 4294.4 | 42 |
| 44 | 6795.1 | 1115.9 | 1385.8 | 4219.4 | 6875.4 | 1145.8 | 1432.2 | 4297.0 | 44 |
| 46 | 6797.8 | 1116.9 | 1387.4 | 4222.0 | 6878.1 | 1146.8 | 1433.8 | 4299.6 | 46 |
| 48 | 6800.5 | 1117.9 | 1388.9 | 4224.5 | 6880.8 | 1147.8 | 1435.3 | 4302.2 | 48 |
| 50 | 6803.2 | 1118.9 | 1390.4 | 4227.1 | 6883.4 | 1148.8 | 1436.9 | 4304.8 | 50 |
| 52 | 6805.9 | 1119.9 | 1392.0 | 4229.7 | 6886.1 | 1149.8 | 1438.5 | 4307.4 | 52 |
| 54 | 6808.5 | 1120.9 | 1393.5 | 4232.3 | 6888.8 | 1150.8 | 1440.0 | 4310.0 | 54 |
| 56 | 6811.2 | 1121.9 | 1395.0 | 4234.8 | 6891.4 | 1151.8 | 1441.6 | 4312.6 | 56 |
| 58 | 6813.9 | 1122.9 | 1396.6 | 4237.4 | 6894.1 | 1152.8 | 1443.1 | 4315.2 | 58 |
| 60 | 6816.6 | 1123.9 | 1398.1 | 4240.0 | 6896.8 | 1153.8 | 1444.7 | 4317.8 | 60 |

| ′ | 74° | | | | 75° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 6896.8 | 1153.8 | 1444.7 | 4317.8 | 6976.4 | 1184.1 | 1492.5 | 4396.7 | 0 |
| 2 | 6899.4 | 1154.8 | 1446.2 | 4320.5 | 6979.0 | 1185.1 | 1494.1 | 4399.4 | 2 |
| 4 | 6902.1 | 1155.8 | 1447.8 | 4323.1 | 6981.7 | 1186.1 | 1495.7 | 4402.1 | 4 |
| 6 | 6904.8 | 1156.8 | 1449.4 | 4325.7 | 6984.3 | 1187.1 | 1497.3 | 4404.7 | 6 |
| 8 | 6907.4 | 1157.8 | 1451.0 | 4328.3 | 6986.9 | 1188.1 | 1499.0 | 4407.4 | 8 |
| 10 | 6910.1 | 1158.8 | 1452.6 | 4330.9 | 6989.6 | 1189.2 | 1500.6 | 4410.0 | 10 |
| 12 | 6912.7 | 1159.8 | 1454.1 | 4333.6 | 6992.2 | 1190.2 | 1502.2 | 4412.7 | 12 |
| 14 | 6915.4 | 1160.8 | 1455.7 | 4336.2 | 6994.9 | 1191.2 | 1503.8 | 4415.3 | 14 |
| 16 | 6918.0 | 1161.8 | 1457.3 | 4338.8 | 6997.5 | 1192.2 | 1505.4 | 4418.0 | 16 |
| 18 | 6920.7 | 1162.8 | 1458.9 | 4341.4 | 7000.1 | 1193.2 | 1507.0 | 4420.7 | 18 |
| 20 | 6923.3 | 1163.9 | 1460.5 | 4344.0 | 7002.8 | 1194.3 | 1508.7 | 4423.3 | 20 |
| 22 | 6926.0 | 1164.9 | 1462.0 | 4346.7 | 7005.4 | 1195.3 | 1510.3 | 4426.0 | 22 |
| 24 | 6928.6 | 1165.9 | 1463.6 | 4349.3 | 7008.0 | 1196.3 | 1512.0 | 4428.6 | 24 |
| 26 | 6931.3 | 1166.9 | 1465.2 | 4351.9 | 7010.7 | 1197.3 | 1513.6 | 4431.3 | 26 |
| 28 | 6933.9 | 1167.9 | 1466.8 | 4354.5 | 7013.3 | 1198.3 | 1515.3 | 4434.0 | 28 |
| 30 | 6936.6 | 1168.9 | 1468.4 | 4357.1 | 7015.9 | 1199.4 | 1516.9 | 4436.6 | 30 |
| 32 | 6939.2 | 1169.9 | 1469.9 | 4359.8 | 7018.6 | 1200.4 | 1518.5 | 4439.3 | 32 |
| 34 | 6941.9 | 1170.9 | 1471.5 | 4362.4 | 7021.2 | 1201.4 | 1520.2 | 4442.0 | 34 |
| 36 | 6944.6 | 1171.9 | 1473.1 | 4365.1 | 7023.9 | 1202.4 | 1521.8 | 4444.6 | 36 |
| 38 | 6947.2 | 1172.9 | 1474.7 | 4367.7 | 7026.5 | 1203.4 | 1523.5 | 4447.3 | 38 |
| 40 | 6949.9 | 1174.0 | 1476.4 | 4370.3 | 7029.1 | 1204.5 | 1525.1 | 4450.0 | 40 |
| 42 | 6952.5 | 1175.0 | 1478.0 | 4373.0 | 7031.8 | 1205.5 | 1526.7 | 4452.7 | 42 |
| 44 | 6955.2 | 1176.0 | 1479.6 | 4375.6 | 7034.4 | 1206.5 | 1528.4 | 4455.3 | 44 |
| 46 | 6957.8 | 1177.0 | 1481.2 | 4378.3 | 7037.0 | 1207.5 | 1530.0 | 4458.0 | 46 |
| 48 | 6960.5 | 1178.0 | 1482.8 | 4380.9 | 7039.7 | 1208.5 | 1531.7 | 4460.7 | 48 |
| 50 | 6963.1 | 1179.0 | 1484.4 | 4383.5 | 7042.3 | 1209.6 | 1533.3 | 4463.4 | 50 |
| 52 | 6965.8 | 1180.0 | 1486.0 | 4386.2 | 7045.0 | 1210.6 | 1534.9 | 4466.0 | 52 |
| 54 | 6968.4 | 1181.0 | 1487.7 | 4388.8 | 7047.6 | 1211.6 | 1536.6 | 4468.7 | 54 |
| 56 | 6971.1 | 1182.0 | 1489.3 | 4391.5 | 7050.2 | 1212.6 | 1538.2 | 4471.4 | 56 |
| 58 | 6973.7 | 1183.0 | 1490.9 | 4394.1 | 7052.9 | 1213.6 | 1539.9 | 4474.1 | 58 |
| 60 | 6976.4 | 1184.1 | 1492.5 | 4396.7 | 7055.5 | 1214.7 | 1541.5 | 4476.7 | 60 |

| ′ | 76° | | | | 77° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M | E. | T. | |
| 0 | 7055.5 | 1214.7 | 1541.5 | 4476.7 | 7134.0 | 1245.6 | 1591.7 | 4557.8 | 0 |
| 2 | 7058.1 | 1215.7 | 1543.2 | 4479.4 | 7136.6 | 1246.6 | 1593.4 | 4560.5 | 2 |
| 4 | 7060.7 | 1216.7 | 1544.9 | 4482.1 | 7139.2 | 1247.7 | 1595.1 | 4563.3 | 4 |
| 6 | 7063.3 | 1217.8 | 1546.5 | 4484.8 | 7141.8 | 1248.7 | 1596.8 | 4566.0 | 6 |
| 8 | 7066.0 | 1218.8 | 1548.2 | 4487.5 | 7144.4 | 1249.8 | 1598.5 | 4568.7 | 8 |
| 10 | 7068.6 | 1219.8 | 1549.9 | 4490.2 | 7147.0 | 1250.8 | 1600.2 | 4571.5 | 10 |
| 12 | 7071.2 | 1220.9 | 1551.5 | 4492.9 | 7149.6 | 1251.8 | 1601.9 | 4574.2 | 12 |
| 14 | 7073.8 | 1221.9 | 1553.2 | 4495.6 | 7152.2 | 1252.9 | 1603.6 | 4576.9 | 14 |
| 16 | 7076.4 | 1222.9 | 1554.9 | 4498.3 | 7154.8 | 1253.9 | 1605.3 | 4579.7 | 16 |
| 18 | 7079.0 | 1224.0 | 1556.5 | 4501.0 | 7157.4 | 1255 0 | 1607.0 | 4582.4 | 18 |
| 20 | 7081.7 | 1225.0 | 1558.2 | 4503.7 | 7160.0 | 1256.0 | 1608.7 | 4585.1 | 20 |
| 22 | 7084.3 | 1226.0 | 1559.9 | 4506.3 | 7162.6 | 1257.0 | 1610.4 | 4587.9 | 22 |
| 24 | 7086.9 | 1227.1 | 1561.5 | 4509.0 | 7165.2 | 1258.1 | 1612.1 | 4590.6 | 24 |
| 26 | 7089.5 | 1228.1 | 1563.2 | 4511.7 | 7167.8 | 1259.1 | 1613.8 | 4593.3 | 26 |
| 28 | 7092.1 | 1229.1 | 1564.9 | 4514.4 | 7170.4 | 1260.2 | 1615.5 | 4596.0 | 28 |
| 30 | 7094.7 | 1230.2 | 1566.5 | 4517.1 | 7173.0 | 1261.2 | 1617.3 | 4598 8 | 30 |
| 32 | 7097.4 | 1231.2 | 1568.2 | 4519.8 | 7175.6 | 1262.2 | 1619.0 | 4601.5 | 32 |
| 34 | 7100.0 | 1232.2 | 1569.9 | 4522.5 | 7178.2 | 1263.3 | 1620.7 | 4604.3 | 34 |
| 36 | 7102.6 | 1233.3 | 1571.5 | 4525.3 | 7180.8 | 1264.3 | 1622.4 | 4607.0 | 36 |
| 38 | 7105.2 | 1234.3 | 1573.2 | 4528.0 | 7183.4 | 1265.4 | 1624.1 | 4609.8 | 38 |
| 40 | 7107.8 | 1235.3 | 1574.8 | 4530.7 | 7186.0 | 1266.4 | 1625.9 | 4612.5 | 40 |
| 42 | 7110.4 | 1236.4 | 1576.4 | 4533.4 | 7188.6 | 1267.4 | 1627.6 | 4615.3 | 42 |
| 44 | 7113.1 | 1237.4 | 1578.1 | 4536.1 | 7191.2 | 1268.5 | 1629.3 | 4618.0 | 44 |
| 46 | 7115.7 | 1238.4 | 1579.8 | 4538.8 | 7193.8 | 1269.5 | 1631.0 | 4620.8 | 46 |
| 48 | 7118.3 | 1239 5 | 1581.5 | 4541.5 | 7196.4 | 1270.6 | 1632.7 | 4623.5 | 48 |
| 50 | 7120.9 | 1240.5 | 1583.2 | 4544.2 | 7199.0 | 1271.6 | 1634.5 | 4626.3 | 50 |
| 52 | 7123.5 | 1241.5 | 1584.9 | 4547.0 | 7201.6 | 1272.7 | 1636.2 | 4629.0 | 52 |
| 54 | 7126.1 | 1242.6 | 1536.6 | 4549.7 | 7204 2 | 1273.7 | 1637.9 | 4631.8 | 54 |
| 56 | 7128.8 | 1243.6 | 1588.3 | 4552.4 | 7206.8 | 1274.8 | 1639.6 | 4634.5 | 56 |
| 58 | 7131.4 | 1244.6 | 1590.0 | 4555.1 | 7209.4 | 1275.8 | 1641.3 | 4637.3 | 58 |
| 60 | 7134.0 | 1245.6 | 1591.7 | 4557.8 | 7212.0 | 1276.9 | 1643.1 | 4640.0 | 60 |

| ′ | 78° | | | | 79° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 7212.0 | 1276.9 | 1643.1 | 4640.0 | 7289.5 | 1308.5 | 1696.0 | 4723.4 | 0 |
| 2 | 7214.6 | 1278.0 | 1644.8 | 4642.8 | 7292.1 | 1309.5 | 1697.7 | 4726.2 | 2 |
| 4 | 7217.2 | 1279.0 | 1646.6 | 4645.6 | 7294.6 | 1310.6 | 1699.5 | 4729.0 | 4 |
| 6 | 7219.7 | 1280.1 | 1648.3 | 4648.3 | 7297.2 | 1311.7 | 1701.3 | 4731.8 | 6 |
| 8 | 7222.3 | 1281.1 | 1650.1 | 4651.1 | 7299.7 | 1312.7 | 1703.1 | 4734.7 | 8 |
| 10 | 7224.9 | 1282.2 | 1651.8 | 4653.9 | 7302.3 | 1313.8 | 1704.9 | 4737.5 | 10 |
| 12 | 7227.5 | 1283.2 | 1653.6 | 4656.7 | 7304.9 | 1314.9 | 1706.6 | 4740.3 | 12 |
| 14 | 7230.1 | 1284.3 | 1655.3 | 4659.4 | 7307.4 | 1315.9 | 1708.4 | 4743.1 | 14 |
| 16 | 7232.7 | 1285.3 | 1657.1 | 4662.2 | 7310.0 | 1317.0 | 1710.2 | 4745.9 | 16 |
| 18 | 7235.2 | 1286.4 | 1658.8 | 4665.0 | 7312.6 | 1318.1 | 1712.0 | 4748.7 | 18 |
| 20 | 7237.8 | 1287.4 | 1660.6 | 4667.7 | 7315.1 | 1319.1 | 1713.8 | 4751.5 | 20 |
| 22 | 7240.4 | 1288.5 | 1662.3 | 4670.5 | 7317.7 | 1320.2 | 1715.6 | 4754.3 | 22 |
| 24 | 7243.0 | 1289.5 | 1664.1 | 4673.3 | 7320.3 | 1321.3 | 1717.4 | 4757.1 | 24 |
| 26 | 7245.6 | 1290.6 | 1665.8 | 4676.0 | 7322.8 | 1322.3 | 1719.2 | 4760.0 | 26 |
| 28 | 7248.2 | 1291.6 | 1667.6 | 4678.8 | 7325.4 | 1323.4 | 1721.0 | 4762.8 | 28 |
| 30 | 7250.7 | 1292.7 | 1669.3 | 4681.6 | 7327.9 | 1324.5 | 1722.8 | 4765.6 | 30 |
| 32 | 7253.3 | 1293.7 | 1671.1 | 4684.4 | 7330.5 | 1325.5 | 1724.6 | 4768.4 | 32 |
| 34 | 7255.9 | 1294.8 | 1672.8 | 4687.2 | 7333.1 | 1326.6 | 1726.4 | 4771.2 | 34 |
| 36 | 7258.5 | 1295.8 | 1674.6 | 4689.9 | 7335.6 | 1327.7 | 1728.2 | 4774.1 | 36 |
| 38 | 7261.1 | 1296.9 | 1676.3 | 4692.7 | 7338.2 | 1328.7 | 1730.0 | 4776.9 | 38 |
| 40 | 7263.7 | 1297.9 | 1678.2 | 4695.5 | 7340.8 | 1329.8 | 1731.9 | 4779.7 | 40 |
| 42 | 7266.2 | 1299.0 | 1679.9 | 4698.3 | 7343.3 | 1330.8 | 1733.7 | 4782.6 | 42 |
| 44 | 7268.8 | 1300.0 | 1681.7 | 4701.1 | 7345.9 | 1331.9 | 1735.5 | 4785.4 | 44 |
| 46 | 7271.4 | 1301.1 | 1683.5 | 4703.9 | 7348.4 | 1333.0 | 1737.3 | 4788.2 | 46 |
| 48 | 7274.0 | 1302.1 | 1685.3 | 4706.7 | 7351.0 | 1334.1 | 1739.1 | 4791.0 | 48 |
| 50 | 7276.6 | 1303.2 | 1687.1 | 4709.5 | 7353.6 | 1335.2 | 1740.9 | 4793.9 | 50 |
| 52 | 7279.2 | 1304.2 | 1688.8 | 4712.2 | 7356.1 | 1336.2 | 1742.7 | 4796.7 | 52 |
| 54 | 7281.7 | 1305.3 | 1690.6 | 4715.0 | 7358.7 | 1337.3 | 1744.5 | 4799.5 | 54 |
| 56 | 7284.3 | 1306.3 | 1692.4 | 4717.8 | 7361.3 | 1338.4 | 1746.3 | 4802.4 | 56 |
| 58 | 7286.9 | 1307.4 | 1694.2 | 4720.6 | 7363.8 | 1339.5 | 1748.1 | 4805.2 | 58 |
| 60 | 7289.5 | 1308.5 | 1696.0 | 4723.4 | 7366.4 | 1340.6 | 1750.0 | 4808.0 | 60 |

| ′ | 80° | | | | 81° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 7366.4 | 1340.6 | 1750.0 | 4808.0 | 7442.7 | 1372.8 | 1805.5 | 4893.9 | 0 |
| 2 | 7368.9 | 1341.7 | 1751.8 | 4810.9 | 7445.2 | 1373.9 | 1807.3 | 4896.8 | 2 |
| 4 | 7371.5 | 1342.7 | 1753.7 | 4813.7 | 7447.7 | 1375.0 | 1809.2 | 4899.7 | 4 |
| 6 | 7374.0 | 1343.8 | 1755.5 | 4816.6 | 7450.3 | 1376.1 | 1811.1 | 4902.6 | 6 |
| 8 | 7376.6 | 1344.9 | 1757.4 | 4819.4 | 7452.8 | 1377.1 | 1813.0 | 4905.4 | 8 |
| 10 | 7379.1 | 1346.0 | 1759.2 | 4822.3 | 7455.3 | 1378.2 | 1814.9 | 4908.3 | 10 |
| 12 | 7381.7 | 1347.0 | 1761.0 | 4825.1 | 7457.8 | 1379.3 | 1816.8 | 4911.2 | 12 |
| 14 | 7384.2 | 1348.1 | 1762.9 | 4828.0 | 7460.4 | 1380.4 | 1818.6 | 4914.1 | 14 |
| 16 | 7386.7 | 1349.2 | 1764.7 | 4830.8 | 7462.9 | 1381.4 | 1820.5 | 4917.0 | 16 |
| 18 | 7389.3 | 1350.3 | 1766.6 | 4833.7 | 7465.4 | 1382.5 | 1822.4 | 4919.9 | 18 |
| 20 | 7391.8 | 1351.3 | 1768.4 | 4836.5 | 7467.9 | 1383.6 | 1824.2 | 4922.8 | 20 |
| 22 | 7394.4 | 1352.4 | 1770.2 | 4839.4 | 7470.4 | 1384.7 | 1826.1 | 4925.7 | 22 |
| 24 | 7396.9 | 1353.5 | 1772.1 | 4842.2 | 7473.0 | 1385.7 | 1828.0 | 4928.6 | 24 |
| 26 | 7399.5 | 1354.6 | 1773.9 | 4845.1 | 7475.5 | 1386.8 | 1829.9 | 4931.5 | 26 |
| 28 | 7402.0 | 1355.6 | 1775.8 | 4847.9 | 7478.0 | 1387.9 | 1831.8 | 4934.4 | 28 |
| 30 | 7404.5 | 1356.7 | 1777.6 | 4850.8 | 7480.5 | 1389.0 | 1833.7 | 4937.2 | 30 |
| 32 | 7407.1 | 1357.8 | 1779.4 | 4853.7 | 7483.1 | 1390.1 | 1835.6 | 4940.2 | 32 |
| 34 | 7409.6 | 1358.9 | 1781.3 | 4856.5 | 7485.6 | 1391.2 | 1837.5 | 4943.1 | 34 |
| 36 | 7412.2 | 1359.9 | 1783.1 | 4859.4 | 7488.1 | 1392.3 | 1839.4 | 4946.0 | 36 |
| 38 | 7414.7 | 1361.0 | 1785.0 | 4862.3 | 7490.6 | 1393.4 | 1841.3 | 4948.9 | 38 |
| 40 | 7417.3 | 1362.1 | 1786.8 | 4865.1 | 7493.2 | 1394.5 | 1843.2 | 4951.8 | 40 |
| 42 | 7419.8 | 1363.2 | 1788.6 | 4868.0 | 7495.7 | 1395.6 | 1845.1 | 4954.7 | 42 |
| 44 | 7422.3 | 1364.2 | 1790.5 | 4870.9 | 7498.2 | 1396.7 | 1847.0 | 4957.6 | 44 |
| 46 | 7424.9 | 1365.3 | 1792.4 | 4873.8 | 7500.7 | 1397.8 | 1848.9 | 4960.6 | 46 |
| 48 | 7427.4 | 1366.4 | 1794.3 | 4876.6 | 7503.3 | 1398.9 | 1850.8 | 4963.5 | 48 |
| 50 | 7430.0 | 1367.5 | 1796.2 | 4879.5 | 7505.8 | 1400.0 | 1852.7 | 4966.4 | 50 |
| 52 | 7432.5 | 1368.5 | 1798.0 | 4882.4 | 7508.3 | 1401.1 | 1854.6 | 4969.3 | 52 |
| 54 | 7435.1 | 1369.6 | 1799.9 | 4885.3 | 7510.8 | 1402.2 | 1856.5 | 4972.2 | 54 |
| 56 | 7437.6 | 1370.7 | 1801.8 | 4888.1 | 7513.3 | 1403.3 | 1858.4 | 4975.1 | 56 |
| 58 | 7440.1 | 1371.8 | 1803.7 | 4891.0 | 7515.9 | 1404.4 | 1860.3 | 4978.0 | 58 |
| 60 | 7442.7 | 1372.8 | 1805.5 | 4893.9 | 7518.4 | 1405.5 | 1862.3 | 4981.0 | 60 |

| ′ | 82° | | | | 83° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 7518.4 | 1405.5 | 1862.3 | 4981.0 | 7593.6 | 1438.5 | 1920.6 | 5069.4 | 0 |
| 2 | 7520.9 | 1406.6 | 1864.2 | 4983.9 | 7596.1 | 1439.6 | 1922.6 | 5072.4 | 2 |
| 4 | 7523.4 | 1407.7 | 1866.1 | 4986.8 | 7598.6 | 1440.7 | 1924.6 | 5075.4 | 4 |
| 6 | 7525.9 | 1408 8 | 1868.1 | 4989.8 | 7601.1 | 1441.8 | 1926.5 | 5078.4 | 6 |
| 8 | 7528.4 | 1409.9 | 1870.0 | 4992.7 | 7603.6 | 1442.9 | 1928.5 | 5081.4 | 8 |
| 10 | 7530.9 | 1411.0 | 1871.9 | 4995.7 | 7606.0 | 1444.0 | 1930.5 | 5084.4 | 10 |
| 12 | 7583.4 | 1412.1 | 1873 9 | 4998.6 | 7608.5 | 1445.1 | 1932.4 | 5087.3 | 12 |
| 14 | 7535.9 | 1413.2 | 1875.8 | 5001.5 | 7611.0 | 1446.2 | 1934.4 | 5090.3 | 14 |
| 16 | 7538.5 | 1414.3 | 1877.7 | 5004.5 | 7613.5 | 1447.3 | 1936.4 | 5093.3 | 16 |
| 18 | 7541.0 | 1415.4 | 1879.7 | 5007.4 | 7616.0 | 1448.4 | 1938.4 | 5096.3 | 18 |
| 20 | 7543.5 | 1416.5 | 1881.6 | 5010.3 | 7618.5 | 1449.6 | 1940.4 | 5099.3 | 20 |
| 22 | 7546.0 | 1417.6 | 1883.5 | 5013.3 | 7621.0 | 1450.7 | 1942.4 | 5102.3 | 22 |
| 24 | 7548.5 | 1418.7 | 1885.5 | 5016.2 | 7623.5 | 1451.8 | 1944.4 | 5105.2 | 24 |
| 26 | 7551.0 | 1419.8 | 1887.4 | 5019.2 | 7626.0 | 1452.9 | 1946.4 | 5108.2 | 26 |
| 28 | 7553.5 | 1420.9 | 1889.3 | 5022.1 | 7628.5 | 1454.0 | 1948.4 | 5111.2 | 28 |
| 30 | 7556.0 | 1422.0 | 1891.3 | 5025.0 | 7630.9 | 1455.1 | 1950.4 | 5114.2 | 30 |
| 32 | 7558.5 | 1423.1 | 1893.2 | 5028.0 | 7633.4 | 1456.2 | 1952.4 | 5117.2 | 32 |
| 34 | 7561.0 | 1424.2 | 1895.1 | 5031.0 | 7635.9 | 1457.3 | 1954.4 | 5120.2 | 34 |
| 36 | 7563.5 | 1425.3 | 1897.1 | 5033.9 | 7638.4 | 1458.4 | 1956.4 | 5123.2 | 36 |
| 38 | 7566.0 | 1426.4 | 1899.0 | 5036.9 | 7640.9 | 1459.5 | 1958.4 | 5126.2 | 38 |
| 40 | 7568.5 | 1427.5 | 1901.0 | 5039.8 | 7643.4 | 1460.7 | 1960.4 | 5129.2 | 40 |
| 42 | 7571.0 | 1428.6 | 1902.9 | 5042.8 | 7645.9 | 1461.8 | 1962.4 | 5132.2 | 42 |
| 44 | 7573.5 | 1429.7 | 1904.9 | 5045.8 | 7648.4 | 1462.9 | 1964.4 | 5135.2 | 44 |
| 46 | 7576.1 | 1430.8 | 1906.9 | 5048.7 | 7650.9 | 1464.0 | 1966.4 | 5138.2 | 46 |
| 48 | 7578.6 | 1431.9 | 1908.8 | 5051.7 | 7653.4 | 1465.1 | 1968.4 | 5141.2 | 48 |
| 50 | 7581.1 | 1433.0 | 1910.8 | 5054.6 | 7655.8 | 1466.2 | 1970.4 | 5144.3 | 50 |
| 52 | 7583.6 | 1434.1 | 1912.8 | 5057.6 | 7658.3 | 1467.3 | 1972.4 | 5147.3 | 52 |
| 54 | 7586.1 | 1435.2 | 1914.7 | 5060.6 | 7660.8 | 1468.4 | 1974.4 | 5150.3 | 54 |
| 56 | 7588.6 | 1436.3 | 1916.7 | 5063.5 | 7663.3 | 1469.5 | 1976.4 | 5153.3 | 56 |
| 58 | 7591.1 | 1437.4 | 1918.7 | 5066.5 | 7665.8 | 1470.6 | 1978.4 | 5156.3 | 58 |
| 60 | 7593.6 | 1438.5 | 1920.6 | 5069.4 | 7668.3 | 1471.8 | 1980.5 | 5159.3 | 60 |

| ′ | 84° | | | | 85° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T | |
| 0 | 7668.3 | 1471.8 | 1980.5 | 5159.3 | 7742.4 | 1505.4 | 2041.8 | 5250.6 | 0 |
| 2 | 7670.8 | 1472.9 | 1982.5 | 5162.3 | 7744.8 | 1506.5 | 2043.9 | 5253.6 | 2 |
| 4 | 7673.2 | 1474.0 | 1984.5 | 5165.3 | 7747.3 | 1507.6 | 2046.0 | 5256.7 | 4 |
| 6 | 7675.7 | 1475.1 | 1986.6 | 5168.4 | 7749.7 | 1508.8 | 2048.0 | 5259.8 | 6 |
| 8 | 7678.2 | 1476.2 | 1988.6 | 5171.4 | 7752.2 | 1509.9 | 2050.1 | 5262.9 | 8 |
| 10 | 7680.6 | 1477.4 | 1990.6 | 5174.4 | 7754.6 | 1511.0 | 2052.2 | 5266 0 | 10 |
| 12 | 7683.1 | 1478.5 | 1992.7 | 5177.5 | 7757.1 | 1512.2 | 2054.2 | 5269.0 | 12 |
| 14 | 7685.6 | 1479.6 | 1994.7 | 5180.5 | 7759 5 | 1513.3 | 2056.3 | 5272.1 | 14 |
| 16 | 7688.1 | 1480.7 | 1996.7 | 5183.5 | 7762.0 | 1514.4 | 2058.4 | 5275.2 | 16 |
| 18 | 7690.5 | 1481.8 | 1998.8 | 5186.6 | 7764 4 | 1515.6 | 2060.5 | 5278.3 | 18 |
| 20 | 7693.0 | 1483.0 | 2000.8 | 5189.6 | 7766.9 | 1516.7 | 2062.6 | 5281.4 | 20 |
| 22 | 7695.5 | 1484.1 | 2002.8 | 5192.6 | 7769.3 | 1517.8 | 2064.7 | 5284.4 | 22 |
| 24 | 7697.9 | 1485.2 | 2004.9 | 5195.6 | 7771.8 | 1519.0 | 2066.8 | 5287.5 | 24 |
| 26 | 7700.4 | 1486.3 | 2006.9 | 5198.7 | 7774.2 | 1520.1 | 2068.9 | 5290.6 | 26 |
| 28 | 7702.9 | 1487.4 | 2008.9 | 5201.7 | 7776.7 | 1521.2 | 2071.0 | 5293.7 | 28 |
| 30 | 7705.3 | 1488.6 | 2011.0 | 5204.7 | 7779.1 | 1522.4 | 2073.1 | 5296.7 | 30 |
| 32 | 7707.8 | 1489.7 | 2013.0 | 5207.8 | 7781.5 | 1523.5 | 2075.2 | 5299.8 | 32 |
| 34 | 7710.3 | 1490.8 | 2015.0 | 5210 8 | 7784.0 | 1524.6 | 2077 3 | 5302.9 | 34 |
| 36 | 7712.8 | 1491.9 | 2017.0 | 5213.9 | 7786.4 | 1525.8 | 2079.4 | 5306.1 | 36 |
| 38 | 7715.2 | 1493.0 | 2019.1 | 5216.9 | 7788.9 | 1526.9 | 2081.5 | 5309.2 | 38 |
| 40 | 7717.7 | 1494.2 | 2021.2 | 5220.0 | 7791.3 | 1528.0 | 2083.7 | 5312.3 | 40 |
| 42 | 7720.2 | 1495.3 | 2023.2 | 5223.1 | 7793.8 | 1529.2 | 2085.8 | 5315.4 | 42 |
| 44 | 7722.6 | 1496.4 | 2025.3 | 5226.1 | 7796.2 | 1530.3 | 2087.9 | 5318.5 | 44 |
| 46 | 7725.1 | 1497.5 | 2027.4 | 5229.2 | 7798 7 | 1531.4 | 2090.0 | 5321.6 | 46 |
| 48 | 7727.6 | 1498.6 | 2029.4 | 5232.2 | 7801.1 | 1532.6 | 2092.1 | 5324.7 | 48 |
| 50 | 7730.0 | 1499.8 | 2031.5 | 5235.3 | 7803.6 | 1533.7 | 2094.2 | 5327.8 | 50 |
| 52 | 7732 5 | 1500.9 | 2033.6 | 5238.3 | 7806.0 | 1534 8 | 2096.3 | 5330 9 | 52 |
| 54 | 7735.0 | 1502.0 | 2035.6 | 5241 4 | 7808.5 | 1536.0 | 2098.4 | 5334.0 | 54 |
| 56 | 7737 5 | 1503.1 | 2037 7 | 5244 5 | 7810.9 | 1537.1 | 2100.6 | 5337.1 | 56 |
| 58 | 7739 9 | 1504.2 | 2039.8 | 5247.5 | 7813 4 | 1538.2 | 2102.7 | 5340.2 | 58 |
| 60 | 7742.4 | 1505 4 | 2041.8 | 5250.6 | 7815.8 | 1539.3 | 2104.8 | 5343.3 | 60 |

| ′ | 86° | | | | 87° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 7815.8 | 1539.3 | 2104.8 | 5343.3 | 7888.5 | 1573.6 | 2169.5 | 5437.5 | 0 |
| 2 | 7818.2 | 1540.4 | 2106.9 | 5346.4 | 7890.9 | 1574.8 | 2171.6 | 5440.7 | 2 |
| 4 | 7820.6 | 1541.6 | 2109.1 | 5349.5 | 7893.3 | 1575.9 | 2173.8 | 5443.9 | 4 |
| 6 | 7823.1 | 1542.7 | 2111.2 | 5352.7 | 7895.7 | 1577.1 | 2176.0 | 5447.1 | 6 |
| 8 | 7825.5 | 1543.9 | 2113.4 | 5355.8 | 7898.1 | 1578.2 | 2178.2 | 5450.3 | 8 |
| 10 | 7827.9 | 1545.0 | 2115.5 | 5358.9 | 7900.5 | 1579.4 | 2180.4 | 5453.4 | 10 |
| 12 | 7830.3 | 1546.1 | 2117.6 | 5362.0 | 7903.0 | 1580.5 | 2182.5 | 5456.6 | 12 |
| 14 | 7832.8 | 1547.3 | 2119.8 | 5365.2 | 7905.4 | 1581.7 | 2184.7 | 5459.8 | 14 |
| 16 | 7835.2 | 1548.4 | 2121.9 | 5368.3 | 7907.8 | 1582.9 | 2186.9 | 5463.0 | 16 |
| 18 | 7837.6 | 1549.6 | 2124.1 | 5371.4 | 7910.2 | 1584.0 | 2189.1 | 5466.2 | 18 |
| 20 | 7840.0 | 1550.7 | 2126.2 | 5374.6 | 7912.6 | 1585.1 | 2191.3 | 5469.4 | 20 |
| 22 | 7842.4 | 1551.8 | 2128.3 | 5377.7 | 7915.0 | 1586.3 | 2193.5 | 5472.5 | 22 |
| 24 | 7844.9 | 1553.0 | 2130.5 | 5380.8 | 7917.4 | 1587.4 | 2195.7 | 5475.7 | 24 |
| 26 | 7847.3 | 1554.1 | 2132.6 | 5383.9 | 7919.8 | 1588.6 | 2197.9 | 5478.9 | 26 |
| 28 | 7849.7 | 1555.3 | 2134.8 | 5387.1 | 7922.2 | 1589.7 | 2200.1 | 5482.1 | 28 |
| 30 | 7852.1 | 1556.4 | 2136.9 | 5390.2 | 7924.6 | 1590.9 | 2202.3 | 5485.3 | 30 |
| 32 | 7854.6 | 1557.5 | 2139.0 | 5393.4 | 7927.1 | 1592.0 | 2204.5 | 5488.5 | 32 |
| 34 | 7857.0 | 1558.7 | 2141.2 | 5396.5 | 7929.5 | 1593.2 | 2206.8 | 5491.7 | 34 |
| 36 | 7859.4 | 1559.8 | 2143.3 | 5399.7 | 7931.9 | 1594.3 | 2209.0 | 5494.9 | 36 |
| 38 | 7861.8 | 1561.0 | 2145.5 | 5402.8 | 7934.3 | 1595.5 | 2211.2 | 5498.1 | 38 |
| 40 | 7864.3 | 1562.1 | 2147.7 | 5406.0 | 7936.7 | 1596.6 | 2213.4 | 5501.3 | 40 |
| 42 | 7866.7 | 1563.2 | 2149.8 | 5409.1 | 7939.1 | 1597.8 | 2215.6 | 5504.5 | 42 |
| 44 | 7869.1 | 1564.4 | 2152.0 | 5412.3 | 7941.5 | 1598.9 | 2217.8 | 5507.7 | 44 |
| 46 | 7871.5 | 1565.5 | 2154.2 | 5415.4 | 7943.9 | 1600.1 | 2220.0 | 5510.9 | 46 |
| 48 | 7874.0 | 1566.7 | 2156.4 | 5418.6 | 7946.3 | 1601.2 | 2222.3 | 5514.1 | 48 |
| 50 | 7876.4 | 1567.8 | 2158.6 | 5421.8 | 7948.7 | 1602.4 | 2224.5 | 5517.3 | 50 |
| 52 | 7878.8 | 1568.9 | 2160.7 | 5424.9 | 7951.2 | 1603.5 | 2226.7 | 5520.5 | 52 |
| 54 | 7881.2 | 1570.1 | 2162.9 | 5428.1 | 7953.6 | 1604.7 | 2228.9 | 5523.7 | 54 |
| 56 | 7883.6 | 1571.2 | 2165.1 | 5431.2 | 7956.0 | 1605.8 | 2231.1 | 5526.9 | 56 |
| 58 | 7886.1 | 1572.4 | 2167.3 | 5434.4 | 7958.4 | 1607.0 | 2233.3 | 5530.1 | 58 |
| 60 | 7888.5 | 1573.6 | 2169.5 | 5437.5 | 7960.8 | 1608.2 | 2235.6 | 5533.3 | 60 |

| ′ | 88° | | | | 89° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 7960.8 | 1608.2 | 2235.6 | 5533.3 | 8032.4 | 1643.0 | 2303.6 | 5630.8 | 0 |
| 2 | 7963.2 | 1609.4 | 2237.8 | 5536.6 | 8034.8 | 1644.1 | 2305.9 | 5634.1 | 2 |
| 4 | 7965.6 | 1610.5 | 2240.1 | 5539.8 | 8037.1 | 1645.3 | 2308.2 | 5637.4 | 4 |
| 6 | 7968.0 | 1611.7 | 2242.3 | 5543.1 | 8039.5 | 1646.5 | 2310.5 | 5640.7 | 6 |
| 8 | 7970.3 | 1612.8 | 2244.6 | 5546.3 | 8041.9 | 1647.7 | 2312.8 | 5644.0 | 8 |
| 10 | 7972.7 | 1614.0 | 2246.8 | 5549.5 | 8044.2 | 1648.9 | 2315.1 | 5647.3 | 10 |
| 12 | 7975.1 | 1615.2 | 2249.1 | 5552.8 | 8046.6 | 1650.0 | 2317.4 | 5650.6 | 12 |
| 14 | 7977.5 | 1616.3 | 2251.3 | 5556.0 | 8049.0 | 1651.2 | 2319.7 | 5653.9 | 14 |
| 16 | 7979.9 | 1617.5 | 2253.6 | 5559.2 | 8051.4 | 1652.4 | 2322.0 | 5657.1 | 16 |
| 18 | 7982.3 | 1618.6 | 2255.8 | 5562.5 | 8053.7 | 1653.6 | 2324.3 | 5660.4 | 18 |
| 20 | 7984.7 | 1619.8 | 2258.1 | 5565.7 | 8056.1 | 1654.8 | 2326.7 | 5663.7 | 20 |
| 22 | 7987.1 | 1621.0 | 2260.4 | 5568.9 | 8058.5 | 1655.9 | 2329.0 | 5667.0 | 22 |
| 24 | 7989.4 | 1622.1 | 2262.7 | 5572.2 | 8060.8 | 1657.1 | 2331.3 | 5670.3 | 24 |
| 26 | 7991.8 | 1623.3 | 2264.9 | 5575.4 | 8063.2 | 1658.3 | 2333.7 | 5673.6 | 26 |
| 28 | 7994.2 | 1624.4 | 2267.2 | 5578.6 | 8065.6 | 1659.5 | 2336.0 | 5676.9 | 28 |
| 30 | 7996.6 | 1625.6 | 2269.5 | 5581.9 | 8067.9 | 1660.7 | 2338.3 | 5680.2 | 30 |
| 32 | 7999.0 | 1626.8 | 2271.7 | 5585.1 | 8070.3 | 1661.8 | 2340.7 | 5683.5 | 32 |
| 34 | 8001.4 | 1627.9 | 2273.9 | 5588.4 | 8073.7 | 1663.0 | 2343.0 | 5686.8 | 34 |
| 36 | 8003.8 | 1629.1 | 2276.2 | 5591.7 | 8075.1 | 1664.2 | 2345.3 | 5690.2 | 36 |
| 38 | 8006.1 | 1630.2 | 2278.5 | 5594.9 | 8077.4 | 1665.4 | 2347.7 | 5693.5 | 38 |
| 40 | 8008.5 | 1631.4 | 2280.8 | 5598.2 | 8079.8 | 1666.6 | 2350.0 | 5696.8 | 40 |
| 42 | 8010.9 | 1632.6 | 2283.0 | 5601.4 | 8082.2 | 1667.7 | 2352.3 | 5700.1 | 42 |
| 44 | 8013.3 | 1633.7 | 2285.3 | 5604.7 | 8084.5 | 1668.8 | 2354.7 | 5703.4 | 44 |
| 46 | 8015.7 | 1634.9 | 2287.6 | 5608.0 | 8086.9 | 1670.0 | 2357.0 | 5706.8 | 46 |
| 48 | 8018.1 | 1636.0 | 2289.9 | 5611.2 | 8089.3 | 1671.2 | 2359.3 | 5710.1 | 48 |
| 50 | 8020.5 | 1637.2 | 2292.2 | 5614.5 | 8091.6 | 1672.4 | 2361.7 | 5713.4 | 50 |
| 52 | 8022.9 | 1638.4 | 2294.4 | 5617.8 | 8094.0 | 1673.5 | 2364.0 | 5716.7 | 52 |
| 54 | 8025.2 | 1639.5 | 2296.7 | 5621.0 | 8096.4 | 1674.7 | 2366.3 | 5720.0 | 54 |
| 56 | 8027.6 | 1640.7 | 2299.0 | 5624.3 | 8098.8 | 1675.9 | 2368.7 | 5723.4 | 56 |
| 58 | 8030.0 | 1641.8 | 2301.3 | 5627.5 | 8101.1 | 1677.1 | 2371.0 | 5726.7 | 58 |
| 60 | 8032.4 | 1643.0 | 2303.6 | 5630.8 | 8103.5 | 1678.3 | 2373.4 | 5730.0 | 60 |

| ′ | 90° | | | | 91° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 8103.5 | 1678.3 | 2373.4 | 5730.0 | 8173.9 | 1713.8 | 2445.1 | 5830.9 | 0 |
| 2 | 8105.8 | 1679.5 | 2375.8 | 5733.3 | 8176.2 | 1715.0 | 2447.5 | 5834.3 | 2 |
| 4 | 8108.2 | 1680.6 | 2378.2 | 5736.7 | 8178.5 | 1716.2 | 2450.0 | 5837.7 | 4 |
| 6 | 8110.5 | 1681.8 | 2380.5 | 5740.0 | 8180.9 | 1717.4 | 2452.4 | 5841.1 | 6 |
| 8 | 8112.9 | 1683.0 | 2382.9 | 5743.4 | 8183.2 | 1718.6 | 2454.8 | 5844.5 | 8 |
| 10 | 8115.2 | 1684.2 | 2385.3 | 5746.7 | 8185.5 | 1719.7 | 2457.2 | 5847.9 | 10 |
| 12 | 8117.6 | 1685.4 | 2387.6 | 5750.0 | 8187.9 | 1720.9 | 2459.7 | 5851.3 | 12 |
| 14 | 8119.9 | 1686.5 | 2390.0 | 5753.4 | 8190.2 | 1722.1 | 2462.1 | 5854.7 | 14 |
| 16 | 8122.3 | 1687.7 | 2392.4 | 5756.7 | 8192.5 | 1723.3 | 2464.5 | 5858.1 | 16 |
| 18 | 8124.6 | 1688.9 | 2394.7 | 5760.1 | 8194.8 | 1724.5 | 2467.0 | 5861.5 | 18 |
| 20 | 8127.0 | 1690.1 | 2397.1 | 5763.4 | 8197.2 | 1725.7 | 2469.4 | 5864.9 | 20 |
| 22 | 8129.3 | 1691.3 | 2399.5 | 5766.8 | 8199.5 | 1726.9 | 2471.9 | 5868.3 | 22 |
| 24 | 8131.7 | 1692.5 | 2401.9 | 5770.1 | 8201.8 | 1728.1 | 2474.3 | 5871.8 | 24 |
| 26 | 8134.0 | 1693.6 | 2404.3 | 5773.5 | 8204.2 | 1729.3 | 2476.7 | 5875.2 | 26 |
| 28 | 8136.4 | 1694.8 | 2406.6 | 5776.9 | 8206.5 | 1730.5 | 2479.2 | 5878.6 | 28 |
| 30 | 8138.7 | 1696.0 | 2409.0 | 5780.2 | 8208.8 | 1731.7 | 2481.6 | 5882.0 | 30 |
| 32 | 8141.1 | 1697.2 | 2411.4 | 5783.6 | 8211.1 | 1732.9 | 2484.1 | 5885.4 | 32 |
| 34 | 8143.4 | 1698.4 | 2413.8 | 5787.0 | 8213.5 | 1734.1 | 2486.5 | 5888.9 | 34 |
| 36 | 8145.8 | 1699.6 | 2416.2 | 5790.3 | 8215.8 | 1735.3 | 2489.0 | 5892.3 | 36 |
| 38 | 8148.1 | 1700.7 | 2418.6 | 5793.7 | 8218.1 | 1736.4 | 2491.5 | 5895.7 | 38 |
| 40 | 8150.4 | 1701.9 | 2421.0 | 5797.1 | 8220.4 | 1737.6 | 2493.9 | 5899.2 | 40 |
| 42 | 8152.8 | 1703.1 | 2423.4 | 5800.4 | 8222.8 | 1738.8 | 2496.4 | 5902.6 | 42 |
| 44 | 8155.1 | 1704.3 | 2425.8 | 5803.8 | 8225.1 | 1740.0 | 2498.9 | 5906.0 | 44 |
| 46 | 8157.5 | 1705.5 | 2428.2 | 5807.2 | 8227.4 | 1741.2 | 2501.3 | 5909.4 | 46 |
| 48 | 8159.8 | 1706.7 | 2430.6 | 5810.6 | 8229.7 | 1742.4 | 2503.8 | 5912.9 | 48 |
| 50 | 8162.2 | 1707.9 | 2433.0 | 5814.0 | 8232.0 | 1743.6 | 2506.3 | 5916.3 | 50 |
| 52 | 8164.5 | 1709.0 | 2435.4 | 5817.3 | 8234.3 | 1744.8 | 2508.7 | 5919.8 | 52 |
| 54 | 8166.8 | 1710.2 | 2437.9 | 5820.7 | 8236.7 | 1746.0 | 2511.2 | 5923.2 | 54 |
| 56 | 8169.2 | 1711.4 | 2440.3 | 5824.1 | 8239.0 | 1747.2 | 2513.7 | 5926.7 | 56 |
| 58 | 8171.5 | 1712.6 | 2442.7 | 5827.5 | 8241.3 | 1748.4 | 2516.2 | 5930.1 | 58 |
| 60 | 8173.9 | 1713.8 | 2445.1 | 5830.9 | 8243.6 | 1749.6 | 2518.7 | 5933.6 | 60 |

| ′ | 92° | | | | 93° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 8243.6 | 1749.6 | 2518.7 | 5933.6 | 8312.8 | 1785.7 | 2594.2 | 6038.2 | 0 |
| 2 | 8245.9 | 1750.8 | 2521.2 | 5937.0 | 8315.1 | 1786.9 | 2596.8 | 6041.7 | 2 |
| 4 | 8248.2 | 1752.0 | 2523.6 | 5940.5 | 8317.4 | 1788.2 | 2599.3 | 6045.2 | 4 |
| 6 | 8250.6 | 1753.2 | 2526.1 | 5944.0 | 8319.7 | 1789.4 | 2601.9 | 6048.7 | 6 |
| 8 | 8252.9 | 1754.4 | 2528.6 | 5947.4 | 8322.0 | 1790.6 | 2604.4 | 6052.2 | 8 |
| 10 | 8255.2 | 1755.6 | 2531.1 | 5950.9 | 8324.3 | 1791.8 | 2607.0 | 6055.8 | 10 |
| 12 | 8257.5 | 1756.8 | 2533.6 | 5954.4 | 8326.6 | 1793.0 | 2609.6 | 6059.3 | 12 |
| 14 | 8259.8 | 1758.0 | 2536.1 | 5957.8 | 8328.8 | 1794.2 | 2612.1 | 6062.8 | 14 |
| 16 | 8262.2 | 1759.2 | 2538.6 | 5961.3 | 8331.1 | 1795.4 | 2614.7 | 6066.4 | 16 |
| 18 | 8264.5 | 1760.4 | 2541.1 | 5964.8 | 8333.3 | 1796.6 | 2617.3 | 6069.9 | 18 |
| 20 | 8266.8 | 1761.6 | 2543.6 | 5968.2 | 8335.6 | 1797.8 | 2619.8 | 6073.4 | 20 |
| 22 | 8269.1 | 1762.8 | 2546.1 | 5971.7 | 8337.9 | 1799.1 | 2622.4 | 6077.0 | 22 |
| 24 | 8271.4 | 1764.0 | 2548.6 | 5975.2 | 8340.2 | 1800.3 | 2625.0 | 6080.5 | 24 |
| 26 | 8273.7 | 1765.2 | 2551.2 | 5978.7 | 8342.5 | 1801.5 | 2627.6 | 6084.1 | 26 |
| 28 | 8276.0 | 1766.4 | 2553.7 | 5982.2 | 8344.8 | 1802.7 | 2630.2 | 6087.6 | 28 |
| 30 | 8278.3 | 1767.6 | 2556.2 | 5985.6 | 8347.1 | 1803.9 | 2632.7 | 6091.2 | 30 |
| 32 | 8280.6 | 1768.8 | 2558.7 | 5989.1 | 8349.4 | 1805.1 | 2635.3 | 6094.7 | 32 |
| 34 | 8282.9 | 1770.0 | 2561.2 | 5992.6 | 8351.7 | 1806.3 | 2637.9 | 6098.3 | 34 |
| 36 | 8285.2 | 1771.2 | 2563.8 | 5996.1 | 8354.0 | 1807.6 | 2640.5 | 6101.8 | 36 |
| 38 | 8287.5 | 1772.5 | 2566.3 | 5999.6 | 8356.3 | 1808.8 | 2643.1 | 6105.4 | 38 |
| 40 | 8289.8 | 1773.7 | 2568.8 | 6003.1 | 8358.5 | 1810.0 | 2645.7 | 6109.0 | 40 |
| 42 | 8292.1 | 1774.9 | 2571.3 | 6006.6 | 8360.8 | 1811.2 | 2648.3 | 6112.5 | 42 |
| 44 | 8294.4 | 1776.1 | 2573.9 | 6010.1 | 8363.1 | 1812.4 | 2650.9 | 6116.1 | 44 |
| 46 | 8296.7 | 1777.3 | 2576.4 | 6013.6 | 8365.4 | 1813.6 | 2653.5 | 6119.7 | 46 |
| 48 | 8299.0 | 1778.5 | 2578.9 | 6017.1 | 8367.7 | 1814.9 | 2656.1 | 6123.2 | 48 |
| 50 | 8301.3 | 1779.7 | 2581.5 | 6020.6 | 8369.9 | 1816.1 | 2658.7 | 6126.8 | 50 |
| 52 | 8303.6 | 1780.9 | 2584.0 | 6024.1 | 8372.2 | 1817.3 | 2661.3 | 6130.4 | 52 |
| 54 | 8305.9 | 1782.1 | 2586.6 | 6027.6 | 8374.5 | 1818.5 | 2663.9 | 6133.9 | 54 |
| 56 | 8308.2 | 1783.3 | 2589.1 | 6031.1 | 8376.8 | 1819.7 | 2666.6 | 6137.5 | 56 |
| 58 | 8310.5 | 1784.5 | 2591.7 | 6034.6 | 8379.1 | 1820.9 | 2669.2 | 6141.1 | 58 |
| 60 | 8312.8 | 1785.7 | 2594.2 | 6038.2 | 8381.3 | 1822.2 | 2671.8 | 6144.7 | 60 |

| ′ | 94° | | | | 95° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 8381.3 | 1822.2 | 2671.8 | 6144.7 | 8449.2 | 1858.9 | 2751.5 | 6253.2 | 0 |
| 2 | 8383.6 | 1823.4 | 2674.4 | 6148.3 | 8451.5 | 1860.1 | 2754.2 | 6256.9 | 2 |
| 4 | 8385.9 | 1824.6 | 2677.0 | 6151.9 | 8453.7 | 1861.3 | 2756.9 | 6260.5 | 4 |
| 6 | 8388.1 | 1825.8 | 2679.7 | 6155.4 | 8456.0 | 1862.6 | 2759.6 | 6264.2 | 6 |
| 8 | 8390.4 | 1827.0 | 2682.3 | 6159.0 | 8458.2 | 1863.8 | 2762.3 | 6267.8 | 8 |
| 10 | 8392.7 | 1828.3 | 2684.9 | 6162.6 | 8460.4 | 1865.0 | 2765.0 | 6271.5 | 10 |
| 12 | 8395.0 | 1829.5 | 2687.6 | 6166.2 | 8462.7 | 1866.3 | 2767.7 | 6275.2 | 12 |
| 14 | 8397.2 | 1830.7 | 2690.2 | 6169.8 | 8464.9 | 1867.5 | 2770.4 | 6278.8 | 14 |
| 16 | 8399.5 | 1831.9 | 2692.8 | 6173.4 | 8467.2 | 1868.7 | 2773.1 | 6282.5 | 16 |
| 18 | 8401.7 | 1833.1 | 2695.6 | 6177.0 | 8469.4 | 1869.9 | 2775.8 | 6286.2 | 18 |
| 20 | 8404.0 | 1834.4 | 2698.1 | 6180.6 | 8471.7 | 1871.2 | 2778.5 | 6289.8 | 20 |
| 22 | 8406.3 | 1835.6 | 2700.8 | 6184.2 | 8473.9 | 1872.4 | 2781.2 | 6293.5 | 22 |
| 24 | 8408.5 | 1836.8 | 2703.4 | 6187.8 | 8476.2 | 1873.6 | 2784.0 | 6297.2 | 24 |
| 26 | 8410.8 | 1838.0 | 2706.1 | 6191.5 | 8478.4 | 1874.9 | 2786.7 | 6300.9 | 26 |
| 28 | 8413.1 | 1839.3 | 2708.7 | 6195.1 | 8480.7 | 1876.1 | 2789.4 | 6304.6 | 28 |
| 30 | 8415.3 | 1840.5 | 2711.4 | 6198.7 | 8482.9 | 1877.3 | 2792.1 | 6308.2 | 30 |
| 32 | 8417.6 | 1841.7 | 2714.0 | 6202.3 | 8485.1 | 1878.6 | 2794.9 | 6311.9 | 32 |
| 34 | 8419.9 | 1842.9 | 2716.7 | 6205.9 | 8487.4 | 1879.8 | 2797.6 | 6315.6 | 34 |
| 36 | 8422.1 | 1844.2 | 2719.3 | 6209.5 | 8489.6 | 1881.0 | 2800.3 | 6319.3 | 36 |
| 38 | 8424.4 | 1845.4 | 2722.0 | 6213.2 | 8491.9 | 1882.3 | 2803.1 | 6323.0 | 38 |
| 40 | 8426.6 | 1846.6 | 2724.7 | 6216.8 | 8494.1 | 1883.5 | 2805.8 | 6326.7 | 40 |
| 42 | 8428.9 | 1847.8 | 2727.3 | 6220.4 | 8496.3 | 1884.8 | 2808.6 | 6330.4 | 42 |
| 44 | 8431.2 | 1849.1 | 2730.0 | 6224.1 | 8498.6 | 1886.0 | 2811.3 | 6334.1 | 44 |
| 46 | 8433.4 | 1850.3 | 2732.7 | 6227.7 | 8500.8 | 1887.2 | 2814.1 | 6337.8 | 46 |
| 48 | 8435.7 | 1851.5 | 2735.4 | 6231.3 | 8503.0 | 1888.5 | 2816.8 | 6341.5 | 48 |
| 50 | 8437.9 | 1852.7 | 2738.0 | 6235.0 | 8505.3 | 1889.7 | 2819.6 | 6345.2 | 50 |
| 52 | 8440.2 | 1854.0 | 2740.7 | 6238.6 | 8507.5 | 1890.9 | 2822.3 | 6349.0 | 52 |
| 54 | 8442.4 | 1855.2 | 2743.4 | 6242.3 | 8509.8 | 1892.2 | 2825.1 | 6352.7 | 54 |
| 56 | 8444.7 | 1856.4 | 2746.1 | 6245.9 | 8512.0 | 1893.4 | 2827.8 | 6356.4 | 56 |
| 58 | 8447.0 | 1857.6 | 2748.8 | 6249.6 | 8514.2 | 1894.6 | 2830.6 | 6360.1 | 58 |
| 60 | 8449.2 | 1858.9 | 2751.5 | 6253.2 | 8516.4 | 1895.9 | 2833.4 | 6363.8 | 60 |

| ′ | 96° | | | | 97° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 8516.4 | 1895.9 | 2833.4 | 6363.8 | 8583.0 | 1933.2 | 2917.5 | 6476.6 | 0 |
| 2 | 8518.7 | 1897.1 | 2836.1 | 6367.5 | 8585.2 | 1934.4 | 2920.3 | 6480.4 | 2 |
| 4 | 8520.9 | 1898.4 | 2838.9 | 6371.3 | 8587.5 | 1935.7 | 2923.2 | 6484.2 | 4 |
| 6 | 8523.1 | 1899.6 | 2841.7 | 6375.0 | 8589.7 | 1936.9 | 2926.0 | 6488.0 | 6 |
| 8 | 8525.4 | 1900.8 | 2844.5 | 6378.7 | 8591.9 | 1938.2 | 2928.9 | 6491.8 | 8 |
| 10 | 8527.6 | 1902.1 | 2847.2 | 6382.5 | 8594.1 | 1939.4 | 2931.7 | 6495.6 | 10 |
| 12 | 8529.8 | 1903.3 | 2850.0 | 6386.2 | 8596.3 | 1940.7 | 2934.6 | 6499.4 | 12 |
| 14 | 8532.0 | 1904.6 | 2852.8 | 6389.9 | 8598.5 | 1941.9 | 2937.5 | 6503.2 | 14 |
| 16 | 8534.3 | 1905.8 | 2855.6 | 6393.7 | 8600.7 | 1943.2 | 2940.3 | 6507.1 | 16 |
| 18 | 8536.5 | 1907.0 | 2858.4 | 6397.4 | 8602.9 | 1944.4 | 2943.2 | 6510.9 | 18 |
| 20 | 8538.7 | 1908.3 | 2861.2 | 6401.2 | 8605.1 | 1945.7 | 2946.1 | 6514.7 | 20 |
| 22 | 8540.9 | 1909.5 | 2864.0 | 6404.9 | 8607.3 | 1946.9 | 2948.9 | 6518.5 | 22 |
| 24 | 8543.2 | 1910.8 | 2866.7 | 6408.7 | 8609.5 | 1948.2 | 2951.8 | 6522.3 | 24 |
| 26 | 8545.4 | 1912.0 | 2869.5 | 6412.4 | 8611.7 | 1949.4 | 2954.7 | 6526.2 | 26 |
| 28 | 8547.6 | 1913.3 | 2872.3 | 6416.2 | 8613.9 | 1950.7 | 2957.6 | 6530.0 | 28 |
| 30 | 8549.8 | 1914.5 | 2875.1 | 6419.9 | 8616.1 | 1952.0 | 2960.4 | 6533.8 | 30 |
| 32 | 8552.0 | 1915.7 | 2877.9 | 6423.7 | 8618.3 | 1953.2 | 2963.3 | 6537.7 | 32 |
| 34 | 8554.3 | 1917.0 | 2880.8 | 6427.5 | 8620.5 | 1954.5 | 2966.2 | 6541.5 | 34 |
| 36 | 8556.5 | 1918.2 | 2883.6 | 6431.2 | 8622.7 | 1955.7 | 2969.1 | 6545.3 | 36 |
| 38 | 8558.7 | 1919.5 | 2886.4 | 6435.0 | 8624.9 | 1957.0 | 2972.0 | 6549.2 | 38 |
| 40 | 8560.9 | 1920.7 | 2889.2 | 6438.8 | 8627.1 | 1958.2 | 2974.9 | 6558.0 | 40 |
| 42 | 8563.1 | 1922.0 | 2892.0 | 6442.5 | 8629.3 | 1959.5 | 2977.8 | 6556.9 | 42 |
| 44 | 8565.3 | 1923.2 | 2894.8 | 6446.3 | 8631.5 | 1960.7 | 2980.7 | 6560.7 | 44 |
| 46 | 8567.6 | 1924.5 | 2897.7 | 6450.1 | 8633.7 | 1962.0 | 2983.6 | 6564.6 | 46 |
| 48 | 8569.8 | 1925.7 | 2900.5 | 6453.9 | 8635.8 | 1963.2 | 2986.5 | 6568.4 | 48 |
| 50 | 8572.0 | 1927.0 | 2903.3 | 6457.6 | 8638.0 | 1964.5 | 2989.4 | 6572.8 | 50 |
| 52 | 8574.2 | 1928.2 | 2906.1 | 6461.4 | 8640.2 | 1965.8 | 2992.3 | 6576.2 | 52 |
| 54 | 8576.4 | 1929.4 | 2909.0 | 6465.2 | 8642.4 | 1967.0 | 2995.2 | 6580.0 | 54 |
| 56 | 8578.6 | 1930.7 | 2911.8 | 6469.0 | 8644.6 | 1968.3 | 2998.1 | 6583.9 | 56 |
| 58 | 8580.8 | 1931.9 | 2914.7 | 6472.8 | 8646.8 | 1969.5 | 3001.1 | 6587.7 | 58 |
| 60 | 8583.0 | 1933.2 | 2917.5 | 6476.6 | 8649.0 | 1970.8 | 3004.0 | 6591.6 | 60 |

| ′ | 98° | | | | 99° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 8649.0 | 1970.8 | 3004.0 | 6591.6 | 8714.3 | 2008.7 | 3092.9 | 6709.0 | 0 |
| 2 | 8651.2 | 1972.0 | 3006.9 | 6595.5 | 8716.4 | 2009.9 | 3095.9 | 6712.9 | 2 |
| 4 | 8653.3 | 1973.3 | 3009.8 | 6599.4 | 8718.6 | 2011.2 | 3098.9 | 6716.9 | 4 |
| 6 | 8655.5 | 1974.6 | 3012.8 | 6603.2 | 8720.7 | 2012.5 | 3101.9 | 6720.8 | 6 |
| 8 | 8657.7 | 1975.8 | 3015.7 | 6607.1 | 8722.9 | 2013.7 | 3104.9 | 6724.8 | 8 |
| 10 | 8659.9 | 1977.1 | 3018.6 | 6611.0 | 8725.1 | 2015.0 | 3107.9 | 6728.8 | 10 |
| 12 | 8662.1 | 1978.3 | 3021.6 | 6614.9 | 8727.2 | 2016.3 | 3111.0 | 6732.7 | 12 |
| 14 | 8664.3 | 1979.6 | 3024.5 | 6618.8 | 8729.4 | 2017.5 | 3114.0 | 6736.7 | 14 |
| 16 | 8666.4 | 1980.9 | 3027.5 | 6622.7 | 8731.5 | 2018.8 | 3117.0 | 6740.7 | 16 |
| 18 | 8668.6 | 1982.1 | 3030.4 | 6626.6 | 8733.7 | 2020.1 | 3120.0 | 6744.6 | 18 |
| 20 | 8670.8 | 1983.4 | 3033.3 | 6630.5 | 8735.9 | 2021.4 | 3123.1 | 6748.6 | 20 |
| 22 | 8673.0 | 1984.6 | 3036.3 | 6634.4 | 8738.0 | 2022.6 | 3126.1 | 6752.6 | 22 |
| 24 | 8675.2 | 1985.9 | 3039.3 | 6638.3 | 8740.2 | 2023.9 | 3129.1 | 6756.6 | 24 |
| 26 | 8677.3 | 1987.2 | 3042.2 | 6642.2 | 8742.3 | 2025.2 | 3132.2 | 6760.6 | 26 |
| 28 | 8679.5 | 1988.4 | 3045.2 | 6646.1 | 8744.5 | 2026.4 | 3135.2 | 6764.6 | 28 |
| 30 | 8681.7 | 1989.7 | 3048.1 | 6650.0 | 8746.6 | 2027.7 | 3138.3 | 6768.6 | 30 |
| 32 | 8683.9 | 1901.0 | 3051.1 | 6653.9 | 8748.8 | 2029.0 | 3141.3 | 6772.6 | 32 |
| 34 | 8686.0 | 1992.2 | 3054.1 | 6657.8 | 8750.9 | 2030.3 | 3144.4 | 6776.6 | 34 |
| 36 | 8688.2 | 1993.5 | 3057.0 | 6661.7 | 8753.1 | 2031.5 | 3147.4 | 6780.6 | 36 |
| 38 | 8690.4 | 1994.7 | 3060.0 | 6665.7 | 8755.3 | 2032.8 | 3150.5 | 6784.6 | 38 |
| 40 | 8692.6 | 1996.0 | 3063.0 | 6669.6 | 8757.4 | 2034.1 | 3153.5 | 6788.6 | 40 |
| 42 | 8694.7 | 1997.3 | 3066.0 | 6673.5 | 8759.5 | 2035.4 | 3156.6 | 6792.6 | 42 |
| 44 | 8696.9 | 1998.5 | 3068.9 | 6677.4 | 8761.7 | 2036.6 | 3159.7 | 6796.6 | 44 |
| 46 | 8699.1 | 1999.8 | 3071.9 | 6681.4 | 8763.8 | 2037.9 | 3162.7 | 6800.6 | 46 |
| 48 | 8701.2 | 2001.1 | 3074.9 | 6685.3 | 8766.0 | 2039.2 | 3165.8 | 6804.6 | 48 |
| 50 | 8703.4 | 2002.3 | 3077.9 | 6689.2 | 8768.1 | 2040.5 | 3168.9 | 6808.6 | 50 |
| 52 | 8705.6 | 2003.6 | 3080.9 | 6693.2 | 8770.3 | 2041.7 | 3172.0 | 6812.6 | 52 |
| 54 | 8707.8 | 2004.9 | 3083.9 | 6697.1 | 8772.4 | 2043.0 | 3175.1 | 6816.7 | 54 |
| 56 | 8709.9 | 2006.1 | 3086.9 | 6701.1 | 8774.6 | 2044.3 | 3178.1 | 6820.7 | 56 |
| 58 | 8712.1 | 2007.4 | 3089.9 | 6705.2 | 8776.7 | 2045.6 | 3181.2 | 6824.7 | 58 |
| 60 | 8714.3 | 2008.7 | 3092.9 | 6709.0 | 8778.9 | 2046.8 | 3184.3 | 6828.8 | 60 |

| ′ | 100° | | | | 101° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 8778.9 | 2046.8 | 3184.3 | 6828.8 | 8842.8 | 2085.3 | 3278.3 | 6951.0 | 0 |
| 2 | 8781.0 | 2048.1 | 3187.4 | 6832.8 | 8844.9 | 2086.6 | 3281.5 | 6955.2 | 2 |
| 4 | 8783.1 | 2049.4 | 3190.5 | 6836.8 | 8847.0 | 2087.8 | 3284.7 | 6959.3 | 4 |
| 6 | 8785.3 | 2050.7 | 3193.6 | 6840.9 | 8849.2 | 2089.1 | 3287.9 | 6963.4 | 6 |
| 8 | 8787.4 | 2051.9 | 3196.7 | 6844.9 | 8851.3 | 2090.4 | 3291.1 | 6967.6 | 8 |
| 10 | 8789.6 | 2053.2 | 3199.8 | 6849.0 | 8853.4 | 2091.7 | 3294.3 | 6971.7 | 10 |
| 12 | 8791.7 | 2054.5 | 3202.9 | 6853.0 | 8855.5 | 2093.0 | 3297.5 | 6975.8 | 12 |
| 14 | 8793.9 | 2055.8 | 3206.0 | 6857.1 | 8857.6 | 2094.3 | 3300.7 | 6980.0 | 14 |
| 16 | 8796.0 | 2057.1 | 3209.1 | 6861.1 | 8859.8 | 2095.6 | 3303.9 | 6984.1 | 16 |
| 18 | 8798.9 | 2058.3 | 3212.2 | 6865.2 | 8861.9 | 2096.9 | 3307.1 | 6988.2 | 18 |
| 20 | 8800.3 | 2059.6 | 3215.4 | 6869.2 | 8864.0 | 2098.2 | 3310.3 | 6992.4 | 20 |
| 22 | 8802.4 | 2060.9 | 3218.5 | 6873.3 | 8866.1 | 2099.4 | 3313.5 | 6996.6 | 22 |
| 24 | 8804.5 | 2062.2 | 3221.6 | 6877.4 | 8868.2 | 2100.7 | 3316.7 | 7000.7 | 24 |
| 26 | 8806.7 | 2063.5 | 3224.7 | 6881.4 | 8870.3 | 2102.0 | 3319.9 | 7004.9 | 26 |
| 28 | 8808.8 | 2064.7 | 3227.9 | 6885.5 | 8872.4 | 2103.3 | 3323.1 | 7009.0 | 28 |
| 30 | 8810.9 | 2066.0 | 3231.0 | 6889.6 | 8874.5 | 2104.6 | 3326.4 | 7013.2 | 30 |
| 32 | 8813.1 | 2067.3 | 3234.1 | 6893.7 | 8876.7 | 2105.9 | 3329.6 | 7017.3 | 32 |
| 34 | 8815.2 | 2068.6 | 3237.3 | 6897.8 | 8878.8 | 2107.2 | 3332.8 | 7021.5 | 34 |
| 36 | 8817.3 | 2069.9 | 3240.4 | 6901.8 | 8880.9 | 2108.5 | 3336.0 | 7025.7 | 36 |
| 38 | 8819.5 | 2071.1 | 3243.5 | 6905.9 | 8883.0 | 2109.8 | 3339.3 | 7029.9 | 38 |
| 40 | 8821.6 | 2072.4 | 3246.7 | 6910.0 | 8885.1 | 2111.1 | 3342.5 | 7084.0 | 40 |
| 42 | 8823.7 | 2073.7 | 3249.8 | 6914.1 | 8887.2 | 2112.4 | 3345.8 | 7038.2 | 42 |
| 44 | 8825.8 | 2075.0 | 3253.0 | 6918.2 | 8889.3 | 2113.6 | 3349.0 | 7042.4 | 44 |
| 46 | 8828.0 | 2076.3 | 3256.2 | 6922.3 | 8891.4 | 2114.9 | 3352.3 | 7046.6 | 46 |
| 48 | 8830.1 | 2077.6 | 3259.3 | 6926.4 | 8893.5 | 2116.2 | 3355.5 | 7050.8 | 48 |
| 50 | 8832.2 | 2078.9 | 3262.5 | 6930.5 | 8895.6 | 2117.5 | 3358.8 | 7055.0 | 50 |
| 52 | 8834.3 | 2080.1 | 3265.7 | 6934.6 | 8897.7 | 2118.8 | 3362.0 | 7059.2 | 52 |
| 54 | 8836.4 | 2081.4 | 3268.8 | 6938.7 | 8899.8 | 2120.1 | 3365.5 | 7063.4 | 54 |
| 56 | 8838.6 | 2082.7 | 3272.0 | 6942.8 | 8901.9 | 2121.4 | 3368.7 | 7067.6 | 56 |
| 58 | 8340.7 | 2084.0 | 3275.2 | 6946.9 | 8904.0 | 2122.7 | 3372.0 | 7071.8 | 58 |
| 60 | 8842.8 | 2085.3 | 3278.3 | 6951.0 | 8906.1 | 2124.0 | 3375.1 | 7076.0 | 60 |

| ′ | 102° | | | | 103° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 8906.1 | 2124.0 | 3375.1 | 7076.0 | 8968.7 | 2163.0 | 3474.6 | 7203.6 | 0 |
| 2 | 8908.2 | 2125.3 | 3378.3 | 7080.2 | 8970.8 | 2164.3 | 3478.0 | 7207.9 | 2 |
| 4 | 8910.3 | 2126.6 | 3381.6 | 7084.4 | 8972.9 | 2165.6 | 3481.4 | 7212.2 | 4 |
| 6 | 8912.4 | 2127.9 | 3384.9 | 7088.6 | 8974.9 | 2166.9 | 3484.7 | 7216.5 | 6 |
| 8 | 8914.5 | 2129.2 | 3388.2 | 7092.8 | 8977.0 | 2168.2 | 3488.1 | 7220.8 | 8 |
| 10 | 8916.6 | 2130.5 | 3391.5 | 7097.1 | 8979.1 | 2169.5 | 3491.5 | 7225.1 | 10 |
| 12 | 8918.7 | 2131.8 | 3394.7 | 7101.3 | 8981.1 | 2170.8 | 3494.9 | 7229.5 | 12 |
| 14 | 8920.8 | 2133.1 | 3398.0 | 7105.5 | 8983.2 | 2172.1 | 3498.3 | 7233.8 | 14 |
| 16 | 8922.9 | 2134.4 | 3401.3 | 7109.7 | 8985.3 | 2173.4 | 3501.6 | 7238.1 | 16 |
| 18 | 8925.0 | 2135.7 | 3404.6 | 7114.0 | 8987.3 | 2174.7 | 3505.3 | 7242.4 | 18 |
| 20 | 8927.0 | 2137.0 | 3407.9 | 7118.2 | 8989.4 | 2176.1 | 3508.4 | 7246.8 | 20 |
| 22 | 8929.1 | 2138.3 | 3411.2 | 7122.4 | 8991.5 | 2177.4 | 3511.8 | 7251.1 | 22 |
| 24 | 8931.2 | 2139.6 | 3414.5 | 7126.7 | 8993.5 | 2178.7 | 3515.2 | 7255.4 | 24 |
| 26 | 8933.3 | 2140.9 | 3417.9 | 7130.9 | 8995.6 | 2180.0 | 3518.7 | 7259.8 | 26 |
| 28 | 8935.4 | 2142.2 | 3421.2 | 7135.2 | 8997.7 | 2181.3 | 3522.1 | 7264.1 | 28 |
| 30 | 8937.5 | 2143.5 | 3424.5 | 7139.4 | 8999.7 | 2182.6 | 3525.5 | 7268.5 | 30 |
| 32 | 8939.6 | 2144.8 | 3427.8 | 7143.7 | 9001.8 | 2183.9 | 3528.9 | 7272.8 | 32 |
| 34 | 8941.6 | 2146.1 | 3431.1 | 7148.0 | 9003.9 | 2185.2 | 3532.3 | 7277.2 | 34 |
| 36 | 8943.7 | 2147.4 | 3434.5 | 7152.2 | 9005.9 | 2186.5 | 3535.7 | 7281.5 | 36 |
| 38 | 8945.8 | 2148.7 | 3437.8 | 7156.5 | 9008.0 | 2187.8 | 3539.2 | 7285.9 | 38 |
| 40 | 8947.9 | 2150.0 | 3441.1 | 7160.7 | 9010.0 | 2189.1 | 3542.6 | 7290.3 | 40 |
| 42 | 8950.0 | 2151.3 | 3444.4 | 7165.0 | 9012.1 | 2190.5 | 3546.0 | 7294.6 | 42 |
| 44 | 8952.1 | 2152.6 | 3447.8 | 7169.3 | 9014.2 | 2191.8 | 3549.5 | 7299.0 | 44 |
| 46 | 8954.1 | 2153.9 | 3451.1 | 7173.6 | 9016.2 | 2193.1 | 3552.9 | 7303.4 | 46 |
| 48 | 8956.2 | 2155.2 | 3454.5 | 7177.9 | 9018.3 | 2194.4 | 3556.3 | 7307.7 | 48 |
| 50 | 8958.3 | 2156.5 | 3457.8 | 7182.1 | 9020.3 | 2195.7 | 3559.8 | 7312.1 | 50 |
| 52 | 8960.4 | 2157.8 | 3461.2 | 7186.4 | 9022.4 | 2197.0 | 3563.2 | 7316.5 | 52 |
| 54 | 8962.5 | 2159.1 | 3464.5 | 7190.7 | 9024.5 | 2198.3 | 3566.7 | 7320.9 | 54 |
| 56 | 8964.5 | 2160.4 | 3467.9 | 7195.0 | 9026.5 | 2199.6 | 3570.2 | 7325.3 | 56 |
| 58 | 8966.6 | 2161.7 | 3471.2 | 7199.3 | 9028.6 | 2200.9 | 3573.6 | 7329.7 | 58 |
| 60 | 8968.7 | 2163.0 | 3474.6 | 7203.6 | 9030.6 | 2202.3 | 3577.1 | 7334.1 | 60 |

| ′ | 104° | | | | 105° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 9030.6 | 2202.3 | 3577.1 | 7334.1 | 9091.8 | 2241.8 | 3682.6 | 7467.5 | 0 |
| 2 | 9032.7 | 2203.6 | 3580.5 | 7338.5 | 9093.9 | 2243.1 | 3686.1 | 7472.0 | 2 |
| 4 | 9034.7 | 2204.9 | 3584.0 | 7342.9 | 9095.9 | 2244.4 | 3689.7 | 7476.5 | 4 |
| 6 | 9036.8 | 2206.2 | 3587.5 | 7347.3 | 9097.9 | 2245.8 | 3693.3 | 7481.0 | 6 |
| 8 | 9038.8 | 2207.5 | 3591.0 | 7351.7 | 9099.9 | 2247.1 | 3696.9 | 7485.5 | 8 |
| 10 | 9040.9 | 2208.8 | 3594.4 | 7356.1 | 9102.0 | 2248.4 | 3700.4 | 7490.0 | 10 |
| 12 | 9042.9 | 2210.2 | 3597.9 | 7360.5 | 9104.0 | 2249.7 | 3704.0 | 7494.5 | 12 |
| 14 | 9045.0 | 2211.5 | 3601.4 | 7364.9 | 9106.0 | 2251.1 | 3707.6 | 7499.1 | 14 |
| 16 | 9047.0 | 2212.8 | 3604.9 | 7369.4 | 9108.0 | 2252.4 | 3711.2 | 7503.6 | 16 |
| 18 | 9049.1 | 2214.1 | 3608.4 | 7373.8 | 9110.1 | 2253.7 | 3714.8 | 7508.1 | 18 |
| 20 | 9051.1 | 2215.4 | 3611.9 | 7378.2 | 9112.1 | 2255.0 | 3718.4 | 7512.6 | 20 |
| 22 | 9053.1 | 2216.7 | 3615.4 | 7382.6 | 9114.1 | 2256.4 | 3722.0 | 7517.2 | 22 |
| 24 | 9055.2 | 2218.0 | 3618.9 | 7387.1 | 9116.1 | 2257.7 | 3725.6 | 7521.7 | 24 |
| 26 | 9057.2 | 2219.4 | 3622.4 | 7391.5 | 9118.1 | 2259.0 | 3729.3 | 7526.3 | 26 |
| 28 | 9059.3 | 2220.7 | 3625.9 | 7396.0 | 9120.2 | 2260.3 | 3732.9 | 7530.8 | 28 |
| 30 | 9061.3 | 2222.0 | 3629.4 | 7400.4 | 9122.2 | 2261.7 | 3736.5 | 7535.3 | 30 |
| 32 | 9063.3 | 2223.3 | 3633.0 | 7404.8 | 9124.2 | 2263.0 | 3740.1 | 7539.9 | 32 |
| 34 | 9065.4 | 2224.6 | 3636.5 | 7409.3 | 9126.2 | 2264.3 | 3743.7 | 7544.4 | 34 |
| 36 | 9067.4 | 2226.0 | 3640.0 | 7413.8 | 9128.2 | 2265.7 | 3747.4 | 7549.0 | 36 |
| 38 | 9069.5 | 2227.3 | 3643.5 | 7418.2 | 9130.2 | 2267.0 | 3751.0 | 7553.6 | 38 |
| 40 | 9071.5 | 2228.6 | 3647.1 | 7422.7 | 9132.3 | 2268.3 | 3754.6 | 7558.1 | 40 |
| 42 | 9073.5 | 2229.9 | 3650.6 | 7427.1 | 9134.3 | 2269.6 | 3758.3 | 7562.7 | 42 |
| 44 | 9075.6 | 2231.2 | 3654.1 | 7431.6 | 9136.3 | 2271.0 | 3761.9 | 7567.3 | 44 |
| 46 | 9077.6 | 2232.6 | 3657.7 | 7436.1 | 9138.3 | 2272.3 | 3765.6 | 7571.8 | 46 |
| 48 | 9079.6 | 2233.9 | 3661.2 | 7440.6 | 9140.3 | 2273.6 | 3769.2 | 7576.4 | 48 |
| 50 | 9081.7 | 2235.2 | 3664.8 | 7445.0 | 9142.3 | 2275.0 | 3772.9 | 7581.0 | 50 |
| 52 | 9083.7 | 2236.5 | 3668.3 | 7449.5 | 9144.3 | 2276.3 | 3776.5 | 7585.6 | 52 |
| 54 | 9085.7 | 2237.8 | 3671.9 | 7454.0 | 9146.3 | 2277.6 | 3780.2 | 7590.2 | 54 |
| 56 | 9087.8 | 2239.2 | 3675.4 | 7458.5 | 9148.3 | 2278.9 | 3783.9 | 7594.8 | 56 |
| 58 | 9089.8 | 2240.5 | 3679.0 | 7463.0 | 9150.4 | 2280.3 | 3787.5 | 7599.4 | 58 |
| 60 | 9091.8 | 2241.8 | 3682.6 | 7467.5 | 9152.4 | 2281.6 | 3791.2 | 7604.0 | 60 |

| ′ | 106° | | | | 107° | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 9152.4 | 2281.6 | 3791.2 | 7604.0 | 9212.2 | 2321.7 | 3903.1 | 7743.7 | 0 |
| 2 | 9154.4 | 2282.9 | 3794.9 | 7608.6 | 9214.2 | 2323.0 | 3906.9 | 7748.4 | 2 |
| 4 | 9156.4 | 2284.3 | 3798.6 | 7613.2 | 9216.2 | 2324.4 | 3910.7 | 7753.1 | 4 |
| 6 | 9158.4 | 2285.6 | 3802.3 | 7617.8 | 9218.1 | 2325.7 | 3914.5 | 7757.8 | 6 |
| 8 | 9160.4 | 2286.9 | 3805.9 | 7622.4 | 9220.1 | 2327.0 | 3918.3 | 7762.5 | 8 |
| 10 | 9162.4 | 2288.3 | 3809.6 | 7627.0 | 9222.1 | 2328.4 | 3922.1 | 7767.3 | 10 |
| 12 | 9164.4 | 2289.6 | 3813.3 | 7631.7 | 9224.1 | 2329.7 | 3925.9 | 7772.0 | 12 |
| 14 | 9166.4 | 2290.9 | 3817.0 | 7636.3 | 9226.1 | 2331.1 | 3929.7 | 7776.7 | 14 |
| 16 | 9168.4 | 2292.3 | 3820.7 | 7640.9 | 9228.1 | 2332.4 | 3933.6 | 7781.5 | 16 |
| 18 | 9170.4 | 2293.6 | 3824.4 | 7645.5 | 9230.0 | 2333.7 | 3937.4 | 7786.2 | 18 |
| 20 | 9172.4 | 2294.9 | 3828.1 | 7650.2 | 9232.0 | 2335.1 | 3941.2 | 7791.0 | 20 |
| 22 | 9174.4 | 2296.3 | 3831.9 | 7654.8 | 9234.0 | 2336.4 | 3945.0 | 7795.7 | 22 |
| 24 | 9176.4 | 2297.6 | 3835.6 | 7659.5 | 9235.9 | 2337.8 | 3948.9 | 7800.5 | 24 |
| 26 | 9178.4 | 2298.9 | 3839.3 | 7664.1 | 9237.9 | 2339.1 | 3952.7 | 7805.2 | 26 |
| 28 | 9180.4 | 2300.3 | 3843.0 | 7668.8 | 9239.9 | 2340.5 | 3956.5 | 7810.0 | 28 |
| 30 | 9182.4 | 2301.6 | 3846.7 | 7673.4 | 9241.9 | 2341.8 | 3960.4 | 7814.7 | 20 |
| 32 | 9184.4 | 2302.9 | 3850.5 | 7678.1 | 9243.8 | 2343.1 | 3964.2 | 7819.5 | 32 |
| 34 | 9186.4 | 2304.3 | 3854.2 | 7682.7 | 9245.8 | 2344.5 | 3968.1 | 7824.3 | 34 |
| 36 | 9188.4 | 2305.6 | 3858.0 | 7687.4 | 9247.8 | 2345.8 | 3971.9 | 7829.1 | 36 |
| 38 | 9190.4 | 2306.9 | 3861.7 | 7692.1 | 9249.7 | 2347.2 | 3975.8 | 7833.8 | 38 |
| 40 | 9192.4 | 2308.3 | 3865.4 | 7696.7 | 9251.7 | 2348.5 | 3979.6 | 7838.6 | 40 |
| 42 | 9194.4 | 2309.6 | 3869.2 | 7701.4 | 9253.7 | 2349.9 | 3983.5 | 7843.4 | 42 |
| 44 | 9196.3 | 2311.0 | 3873.0 | 7706.1 | 9255.6 | 2351.2 | 3987.4 | 7848.2 | 44 |
| 46 | 9198.3 | 2312.3 | 3876.7 | 7710.8 | 9257.6 | 2352.6 | 3991.3 | 7853.0 | 46 |
| 48 | 9200.3 | 2313.6 | 3880.5 | 7715.5 | 9259.6 | 2353.9 | 3995.1 | 7857.8 | 48 |
| 50 | 9202.3 | 2315.0 | 3884.2 | 7720.1 | 9261.5 | 2355.3 | 3999.0 | 7862.6 | 50 |
| 52 | 9204.3 | 2316.3 | 3888.0 | 7724.8 | 9263.5 | 2356.6 | 4002.9 | 7867.4 | 52 |
| 54 | 9206.3 | 2317.7 | 3891.8 | 7729.5 | 9265.4 | 2358.0 | 4006.8 | 7872.2 | 54 |
| 56 | 9208.2 | 2319.0 | 3895.6 | 7734.2 | 9267.4 | 2359.3 | 4010.7 | 7877.0 | 56 |
| 58 | 9210.2 | 2320.3 | 3899.3 | 7739.0 | 9269.4 | 2360.7 | 4014.6 | 7881.9 | 58 |
| 60 | 9212.2 | 2321.7 | 3903.1 | 7743.7 | 9271.3 | 2362.0 | 4018.5 | 7886.7 | 60 |

| ′ | 108° | | | | 109° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 9271.3 | 2362.0 | 4018.5 | 7886.7 | 9329.8 | 2402.6 | 4137.4 | 8033.2 | 0 |
| 2 | 9273.3 | 2363.3 | 4022.4 | 7891.5 | 9331.7 | 2403.9 | 4141.4 | 8038.1 | 2 |
| 4 | 9275.3 | 2364.7 | 4026.3 | 7896.3 | 9333.6 | 2405.3 | 4145.4 | 8043.1 | 4 |
| 6 | 9277.2 | 2366.0 | 4030.2 | 7901.2 | 9335.6 | 2406.6 | 4149.5 | 8048.0 | 6 |
| 8 | 9279.2 | 2367.4 | 4034.1 | 7906.0 | 9337.5 | 2408.0 | 4153.5 | 8053.0 | 8 |
| 10 | 9281.1 | 2368.7 | 4038.0 | 7910.8 | 9339.4 | 2409.4 | 4157.5 | 8057.9 | 10 |
| 12 | 9283.1 | 2370.1 | 4042.0 | 7915.7 | 9341.4 | 2410.7 | 4161.6 | 8062.9 | 12 |
| 14 | 9285.0 | 2371.4 | 4045.9 | 7920.5 | 9343.3 | 2412.1 | 4165.6 | 8067.9 | 14 |
| 16 | 9287.0 | 2372.8 | 4049.8 | 7925.4 | 9345.2 | 2413.4 | 4169.7 | 8072.8 | 16 |
| 18 | 9288.9 | 2374.1 | 4053.8 | 7930.3 | 9347.2 | 2414.8 | 4173.8 | 8077.8 | 18 |
| 20 | 9290.9 | 2375.5 | 4057.7 | 7935.1 | 9349.1 | 2416.2 | 4177.8 | 8082.8 | 20 |
| 22 | 9292.8 | 2376.8 | 4061.6 | 7940.0 | 9351.0 | 2417.5 | 4181.9 | 8087.8 | 22 |
| 24 | 9294.8 | 2378.2 | 4065.6 | 7944.8 | 9352.9 | 2418.9 | 4186.0 | 8092.8 | 24 |
| 26 | 9296.7 | 2379.5 | 4069.5 | 7949.7 | 9354.9 | 2420.2 | 4190.0 | 8097.8 | 26 |
| 28 | 9298.7 | 2380.9 | 4073.5 | 7954.6 | 9356.8 | 2421.6 | 4193.1 | 8102.8 | 28 |
| 30 | 9300.6 | 2382.3 | 4077.5 | 7959.5 | 9358.7 | 2423.0 | 4198.2 | 8107.8 | 30 |
| 32 | 9302.6 | 2383.6 | 4081.4 | 7964.4 | 9360.6 | 2424.3 | 4202.3 | 8112.8 | 32 |
| 34 | 9304.5 | 2385.0 | 4085.4 | 7969.3 | 9362.6 | 2425.7 | 4206.4 | 8117.8 | 34 |
| 36 | 9306.5 | 2386.3 | 4089.4 | 7974.1 | 9364.5 | 2427.0 | 4210.5 | 8122.8 | 36 |
| 38 | 9308.4 | 2387.7 | 4093.4 | 7979.0 | 9366.4 | 2428.4 | 4214.6 | 8127.8 | 38 |
| 40 | 9310.4 | 2389.0 | 4097.3 | 7983.9 | 9368.3 | 2430.0 | 4218.7 | 8132.8 | 40 |
| 42 | 9312.3 | 2390.4 | 4101.3 | 7988.8 | 9370.2 | 2431.1 | 4222.8 | 8137.9 | 42 |
| 44 | 9314.2 | 2391.7 | 4105.3 | 7993.8 | 9372.2 | 2432.5 | 4226.9 | 8142.9 | 44 |
| 46 | 9316.2 | 2393.1 | 4109.3 | 7998.7 | 9374.1 | 2433.9 | 4231.0 | 8147.9 | 46 |
| 48 | 9318.1 | 2394.4 | 4113.3 | 8003.6 | 9376.0 | 2435.2 | 4235.1 | 8153.0 | 48 |
| 50 | 9320.1 | 2395.8 | 4117.3 | 8008.5 | 9377.9 | 2436.6 | 4239.3 | 8158.0 | 50 |
| 52 | 9322.0 | 2397.2 | 4121.3 | 8013.4 | 9379.8 | 2438.0 | 4243.4 | 8163.1 | 52 |
| 54 | 9323.9 | 2398.5 | 4125.3 | 8018.4 | 9381.7 | 2439.3 | 4247.5 | 8168.1 | 54 |
| 56 | 9325.9 | 2399.9 | 4129.3 | 8023.3 | 9383.7 | 2440.7 | 4251.7 | 8173.2 | 56 |
| 58 | 9327.8 | 2401.2 | 4133.4 | 8028.2 | 9385.6 | 2442.1 | 4255.8 | 8178.2 | 58 |
| 60 | 9329.8 | 2402.6 | 4137.4 | 8033.2 | 9387.5 | 2443.4 | 4260.0 | 8183.3 | 60 |

| ′ | 110° | | | | 111° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 9387.5 | 2443.4 | 4260.0 | 8183.3 | 9444.5 | 2484.5 | 4386.4 | 8337.2 | 0 |
| 2 | 9389.4 | 2444.8 | 4264.1 | 8188.4 | 9446.4 | 2485.9 | 4390.7 | 8342.4 | 2 |
| 4 | 9391.3 | 2446.1 | 4268.3 | 8193.4 | 9448.3 | 2487.2 | 4395 0 | 8347.6 | 4 |
| 6 | 9393 2 | 2447.5 | 4272.4 | 8198.5 | 9450.1 | 2488.6 | 4399.3 | 8352.8 | 6 |
| 8 | 9395.1 | 2448.9 | 4276.6 | 8203.6 | 9452.0 | 2490.0 | 4403.6 | 8358.0 | 8 |
| 10 | 9397.0 | 2450.2 | 4280.8 | 8208.7 | 9453.9 | 2491.4 | 4407.9 | 8363.2 | 10 |
| 12 | 9398.9 | 2451.6 | 4284.9 | 8213.8 | 9455.8 | 2492.7 | 4412.2 | 8368.5 | 12 |
| 14 | 9400.8 | 2453.0 | 4289.1 | 8218.9 | 9457.7 | 2494.1 | 4416.5 | 8373.7 | 14 |
| 16 | 9402.7 | 2454.3 | 4293.3 | 8224.0 | 9459.6 | 2495.5 | 4420.8 | 8378 9 | 16 |
| 18 | 9404.7 | 2455.7 | 4297.5 | 8229.1 | 9461.4 | 2496.9 | 4425.1 | 8384 1 | 18 |
| 20 | 9406.6 | 2457.1 | 4301.7 | 8234.2 | 9463.3 | 2498.2 | 4429.5 | 8389.4 | 20 |
| 22 | 9408.5 | 2458.4 | 4305.9 | 8239.3 | 9465.2 | 2499.6 | 4433.8 | 8394 6 | 22 |
| 24 | 9410.4 | 2459 8 | 4310.1 | 8244.4 | 9467.1 | 2501.0 | 4438.1 | 8399.9 | 24 |
| 26 | 9412.3 | 2461.2 | 4314.3 | 8249.5 | 9469.0 | 2502.4 | 4442.5 | 8405.1 | 26 |
| 28 | 9414.2 | 2462.6 | 4318.5 | 8254.6 | 9470.8 | 2503.8 | 4446.8 | 8410.4 | 28 |
| 30 | 9416.1 | 2463.9 | 4322.7 | 8259.8 | 9472.7 | 2505.1 | 4451.2 | 8415.6 | 30 |
| 32 | 9418.0 | 2465.3 | 4326.9 | 8264.9 | 9474.6 | 2506.5 | 4455.5 | 8420.9 | 32 |
| 34 | 9419.9 | 2466.7 | 4331.1 | 8270.0 | 9476.5 | 2507.9 | 4459.9 | 8426.2 | 34 |
| 36 | 9421.8 | 2468.0 | 4335.4 | 8275.2 | 9478.3 | 2509.3 | 4464.2 | 8431.4 | 36 |
| 38 | 9423.7 | 2469.4 | 4339.6 | 8280.3 | 9480.2 | 2510.6 | 4468.6 | 8436.7 | 38 |
| 40 | 9425.6 | 2470.8 | 4343.8 | 8285.5 | 9482.1 | 2512.0 | 4473.0 | 8442.0 | 40 |
| 42 | 9427.5 | 2472.1 | 4348.1 | 8290.6 | 9484.0 | 2513.4 | 4477.3 | 8447.3 | 42 |
| 44 | 9429.3 | 2473.5 | 4352.3 | 8295.8 | 9485.8 | 2514.8 | 4481.7 | 8452.6 | 44 |
| 46 | 9431.2 | 2474.9 | 4356.6 | 8300.9 | 9487.7 | 2516.2 | 4486.1 | 8457.9 | 46 |
| 48 | 9433.1 | 2476.3 | 4360.8 | 8306.1 | 9489.6 | 2517.5 | 4490.5 | 8463.2 | 48 |
| 50 | 9435.0 | 2477.6 | 4365.1 | 8311.3 | 9491.4 | 2518.9 | 4494.9 | 8468.5 | 50 |
| 52 | 9436.9 | 2479.0 | 4369.3 | 8316.5 | 9493.3 | 2520.3 | 4499.3 | 8473.8 | 52 |
| 54 | 9438.8 | 2480.4 | 4373.6 | 8321.6 | 9495.2 | 2521.7 | 4503.7 | 8479.1 | 54 |
| 56 | 9440.7 | 2481.7 | 4377.9 | 8326.8 | 9497.0 | 2523.1 | 4508.1 | 8484.4 | 56 |
| 58 | 9442.6 | 2483.1 | 4382.2 | 8332.0 | 9498.9 | 2524.5 | 4512.5 | 8489.7 | 58 |
| 60 | 9444.5 | 2484.5 | 4386.4 | 8337.2 | 9500.8 | 2525.8 | 4516.9 | 8495.1 | 60 |

| ′ | 112° | | | | 113° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 9500.8 | 2525.8 | 4516.9 | 8495.1 | 9556.3 | 2567.4 | 4651.6 | 8657.1 | 0 |
| 2 | 9502.6 | 2527.2 | 4521.4 | 8500.4 | 9558.2 | 2568.8 | 4656.2 | 8662.6 | 2 |
| 4 | 9504.5 | 2528.6 | 4525.8 | 8505.8 | 9560.0 | 2570.2 | 4660.8 | 8668.0 | 4 |
| 6 | 9506.4 | 2530.0 | 4530.2 | 8511.1 | 9561.8 | 2571.6 | 4665.4 | 8673.5 | 6 |
| 8 | 9508.2 | 2531.4 | 4534.6 | 8516.4 | 9563.7 | 2573.0 | 4669.9 | 8679.0 | 8 |
| 10 | 9510.1 | 2532.7 | 4539.1 | 8521.8 | 9565.5 | 2574.4 | 4674.5 | 8684.5 | 10 |
| 12 | 9511.9 | 2534.1 | 4543.5 | 8527.1 | 9567.4 | 2575.8 | 4679.1 | 8690.0 | 12 |
| 14 | 9513.8 | 2535.5 | 4548.0 | 8532.5 | 9569.2 | 2577.1 | 4683.7 | 8695.5 | 14 |
| 16 | 9515.7 | 2536.9 | 4552.4 | 8537.9 | 9571.0 | 2578.5 | 4688.3 | 8701.0 | 16 |
| 18 | 9517.5 | 2538.3 | 4556.9 | 8543.2 | 9572.9 | 2579.9 | 4692.9 | 8706.5 | 18 |
| 20 | 9519.4 | 2539.7 | 4561.3 | 8548.6 | 9574.7 | 2581.3 | 4697.5 | 8712.0 | 20 |
| 22 | 9521.2 | 2541.0 | 4565.8 | 8554.0 | 9576.5 | 2582.7 | 4702.1 | 8717.6 | 22 |
| 24 | 9523.1 | 2542.4 | 4570.3 | 8559.4 | 9578.4 | 2584.1 | 4706.8 | 8723.1 | 24 |
| 26 | 9524.9 | 2543.8 | 4574.8 | 8564.8 | 9580 2 | 2585.5 | 4711.4 | 8728.6 | 26 |
| 28 | 9526.8 | 2545.2 | 4579.3 | 8570.2 | 9582.0 | 2586.9 | 4716.0 | 8734.2 | 28 |
| 30 | 9528.6 | 2546.6 | 4583.7 | 8575.6 | 9583.8 | 2588.3 | 4720.6 | 8739.7 | 30 |
| 32 | 9530 5 | 2548.0 | 4588.2 | 8581.0 | 9585.7 | 2589.7 | 4725.3 | 8745.3 | 32 |
| 34 | 9532.3 | 2549.4 | 4592.7 | 8586.4 | 9587.5 | 2591.1 | 4729.9 | 8750.8 | 34 |
| 36 | 9534.2 | 2550.7 | 4597.2 | 8591.8 | 9589.3 | 2592.5 | 4734.6 | 8756.4 | 36 |
| 38 | 9336 0 | 2552.1 | 4601.7 | 8597.2 | 9591.1 | 2593.9 | 4739.2 | 8761.9 | 38 |
| 40 | 9537.9 | 2553.5 | 4606 2 | 8602.6 | 9593.0 | 2595.3 | 4743.9 | 8767.5 | 40 |
| 42 | 9539.7 | 2554.9 | 4610 8 | 8608.0 | 9594.8 | 2596.7 | 4748.5 | 8773.1 | 42 |
| 44 | 9541.6 | 2556.3 | 4615.3 | 8613.5 | 9596.6 | 2598.1 | 4753.2 | 8778.6 | 44 |
| 46 | 9543.4 | 2557.7 | 4619.8 | 8618.9 | 9598.4 | 2599.4 | 4757 9 | 8784.2 | 46 |
| 48 | 9545.3 | 2559.1 | 4624.3 | 8624.3 | 9600.3 | 2600.8 | 4762.6 | 8789.8 | 48 |
| 50 | 9547.1 | 2560.5 | 4628.9 | 8629.8 | 9602.1 | 2602.2 | 4767.2 | 8795.4 | 50 |
| 52 | 9549.0 | 2561.8 | 4633.4 | 8635.2 | 9603.9 | 2603.6 | 4771.9 | 8801.0 | 52 |
| 54 | 9550.8 | 2563 2 | 4638.0 | 8640.7 | 9605.7 | 2605.0 | 4776.6 | 8806.6 | 54 |
| 56 | 9552.6 | 2564.6 | 4642.5 | 8646.2 | 9607.5 | 2606.4 | 4781.3 | 8812.2 | 56 |
| 58 | 9554 5 | 2566.0 | 4647 1 | 8651 6 | 9609.4 | 2607.8 | 4786 0 | 8817.8 | 58 |
| 60 | 9556.3 | 2567.4 | 4651.6 | 8657.1 | 9611.2 | 2609.2 | 4790.7 | 8823.4 | 60 |

| ′ | 114° | | | | 115° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 9611.2 | 2609.2 | 4790.7 | 8823.4 | 9665.3 | 2651.3 | 4934.4 | 8994.3 | 0 |
| 2 | 9613.0 | 2610.6 | 4795.5 | 8829.1 | 9667.1 | 2652.7 | 4939.3 | 9000.1 | 2 |
| 4 | 9614.8 | 2612.0 | 4800.2 | 8834.7 | 9668.8 | 2654.1 | 4944.2 | 9005.9 | 4 |
| 6 | 9616.6 | 2613.4 | 4804.9 | 8840.3 | 9670.6 | 2655.5 | 4949.1 | 9011.6 | 6 |
| 8 | 9618.4 | 2614.8 | 4809.6 | 8846.0 | 9672.4 | 2656.9 | 4954.0 | 9017.4 | 8 |
| 10 | 9620.2 | 2616.2 | 4814.4 | 8851.6 | 9674.2 | 2658.3 | 4958.9 | 9023.2 | 10 |
| 12 | 9622.0 | 2617.6 | 4819.1 | 8857.2 | 9676.0 | 2659.7 | 4963.8 | 9029.0 | 12 |
| 14 | 9623.8 | 2619.0 | 4823.9 | 8862.9 | 9677.8 | 2661.1 | 4968.7 | 9034.8 | 14 |
| 16 | 9625.7 | 2620.4 | 4828.6 | 8868.5 | 9679.6 | 2662.5 | 4973.6 | 9040.7 | 16 |
| 18 | 9627.5 | 2621.8 | 4833.4 | 8874.2 | 9681.4 | 2663.9 | 4978.5 | 9046.5 | 18 |
| 20 | 9629.3 | 2623.2 | 4838.1 | 8879.9 | 9683.1 | 2665.4 | 4983.4 | 9052.3 | 20 |
| 22 | 9631.1 | 2624.6 | 4842.9 | 8885.5 | 9684.9 | 2666.8 | 4988.3 | 9058.1 | 22 |
| 24 | 9632.9 | 2626.0 | 4847.7 | 8891.2 | 9686.7 | 2668.2 | 4993.3 | 9064.0 | 24 |
| 26 | 9634.7 | 2627.4 | 4852.4 | 8896.9 | 9688.5 | 2669.6 | 4998.2 | 9069.8 | 26 |
| 28 | 9636.5 | 2628.8 | 4857.2 | 8902.6 | 9690.3 | 2671.0 | 5003.2 | 9075.7 | 28 |
| 30 | 9638.3 | 2630.2 | 4862.0 | 8908.3 | 9692.0 | 2672.4 | 5008.1 | 9081.5 | 30 |
| 32 | 9640.1 | 2631.6 | 4866.8 | 8914.0 | 9693.8 | 2673.8 | 5013.1 | 9087.4 | 32 |
| 34 | 9641.9 | 2633.0 | 4871.6 | 8919.7 | 9695.6 | 2675.2 | 5018.0 | 9093.2 | 34 |
| 36 | 9643.7 | 2634.4 | 4876.4 | 8925.4 | 9697.4 | 2676.6 | 5023.0 | 9099.1 | 36 |
| 38 | 9645.5 | 2635.8 | 4881.2 | 8931.1 | 9699.1 | 2678.0 | 5028.0 | 9105.0 | 38 |
| 40 | 9647.3 | 2637.2 | 4885.0 | 8936.8 | 9700.9 | 2679.5 | 5032.9 | 9110.8 | 40 |
| 42 | 9649.1 | 2638.6 | 4890.9 | 8942.6 | 9702.7 | 2680.9 | 5037.9 | 9116.7 | 42 |
| 44 | 9650.9 | 2640.0 | 4895.7 | 8948.3 | 9704.5 | 2682.3 | 5042.9 | 9122.6 | 44 |
| 46 | 9652.7 | 2641.4 | 4900.5 | 8954.0 | 9706.2 | 2683.7 | 5047.9 | 9128.5 | 46 |
| 48 | 9654.5 | 2642.9 | 4905.3 | 8959.8 | 9708.0 | 2685.1 | 5052.9 | 9134.4 | 48 |
| 50 | 9656.3 | 2644.3 | 4910.2 | 8965.5 | 9709.8 | 2686.5 | 5057.9 | 9140.3 | 50 |
| 52 | 9658.1 | 2645.7 | 4915.0 | 8971.3 | 9711.6 | 2687.9 | 5062.9 | 9146.2 | 52 |
| 54 | 9659.9 | 2647.1 | 4919.9 | 8977.0 | 9713.3 | 2689.3 | 5067.9 | 9152.1 | 54 |
| 56 | 9661.7 | 2648.5 | 4924.7 | 8982.8 | 9715.1 | 2690.7 | 5072.9 | 9158.1 | 56 |
| 58 | 9663.5 | 2649.9 | 4929.6 | 8988.5 | 9716.9 | 2692.2 | 5078.0 | 9164.0 | 58 |
| 60 | 9665.3 | 2651.3 | 4934.4 | 8994.3 | 9718.6 | 2693.6 | 5083.0 | 9169.9 | 60 |

| ′ | 116° | | | | 117° | | | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | L. C. | M. | E. | T. | L. C. | M. | E. | T. | |
| 0 | 9718.6 | 2693.6 | 5083.0 | 9169.9 | 9771.3 | 2736.1 | 5236.6 | 9350.5 | 0 |
| 2 | 9720.4 | 2695.0 | 5088.0 | 9175.9 | 9773.0 | 2737.5 | 5241.8 | 9356.6 | 2 |
| 4 | 9722.2 | 2696.4 | 5093.1 | 9181.8 | 9774.7 | 2738.9 | 5247.0 | 9362.7 | 4 |
| 6 | 9723.9 | 2697.8 | 5098.1 | 9188.8 | 9776.5 | 2740.4 | 5252.2 | 9368.9 | 6 |
| 8 | 9725.7 | 2699.2 | 5103.2 | 9193.7 | 9778.2 | 2741.8 | 5257.4 | 9375.0 | 8 |
| 10 | 9727.4 | 2700.6 | 5108.2 | 9199.7 | 9779.9 | 2743.2 | 5262.6 | 9381.1 | 10 |
| 12 | 9729.2 | 2702.1 | 5113.3 | 9205.6 | 9781.7 | 2744.6 | 5267.9 | 9387.3 | 12 |
| 14 | 9731.0 | 2703.5 | 5118.4 | 9211.6 | 9783.4 | 2746.0 | 5273.1 | 9393.4 | 14 |
| 16 | 9732.7 | 2704.9 | 5123.4 | 9217.6 | 9785.2 | 2747.5 | 5278.4 | 9399.5 | 16 |
| 18 | 9734.5 | 2706.3 | 5128.5 | 9223.6 | 9786.9 | 2748.9 | 5283.6 | 9405.7 | 18 |
| 20 | 9736.3 | 2707.7 | 5133.6 | 9229.6 | 9788.6 | 2750.3 | 5288.9 | 9411.9 | 20 |
| 22 | 9738.0 | 2709.1 | 5138.7 | 9235.5 | 9790.4 | 2751.7 | 5294.2 | 9418.0 | 22 |
| 24 | 9739.8 | 2710.6 | 5143.8 | 9241.5 | 9792.1 | 2753.2 | 5299.5 | 9424.2 | 24 |
| 26 | 9741.5 | 2712.0 | 5148.9 | 9247.6 | 9793.8 | 2754.6 | 5304.7 | 9430.4 | 26 |
| 28 | 9743.3 | 2713.4 | 5154.0 | 9253.6 | 9795.6 | 2756.0 | 5310.0 | 9436.6 | 28 |
| 30 | 9745.0 | 2714.8 | 5159.1 | 9259.6 | 9797.3 | 2757.4 | 5315.3 | 9442.8 | 30 |
| 32 | 9746.8 | 2716.2 | 5164.2 | 9265.6 | 9799.0 | 2758.9 | 5320.6 | 9449.0 | 32 |
| 34 | 9748.5 | 2717.6 | 5169.4 | 9271.6 | 9800.7 | 2760.3 | 5325.9 | 9455.2 | 34 |
| 36 | 9750.3 | 2719.1 | 5174.5 | 9277.7 | 9802.5 | 2761.7 | 5331.2 | 9461.4 | 36 |
| 38 | 9752.0 | 2720.5 | 5179.7 | 9283.7 | 9804.2 | 2763.1 | 5336.5 | 9467.6 | 38 |
| 40 | 9753.8 | 2721.9 | 5184.8 | 9289.8 | 9805.9 | 2764.6 | 5341.8 | 9473.8 | 40 |
| 42 | 9755.6 | 2723.3 | 5190.0 | 9295.8 | 9807.7 | 2766.0 | 5347.2 | 9480.0 | 42 |
| 44 | 9757.3 | 2724.7 | 5195.1 | 9301.9 | 9809.4 | 2767.4 | 5352.5 | 9486.3 | 44 |
| 46 | 9759.0 | 2726.2 | 5200.3 | 9307.9 | 9811.1 | 2768.8 | 5357.9 | 9492.5 | 46 |
| 48 | 9760.8 | 2727.6 | 5205.4 | 9314.0 | 9812.8 | 2770.3 | 5363.2 | 9498.7 | 48 |
| 50 | 9762.5 | 2729.0 | 5210.6 | 9320.1 | 9814.5 | 2771.7 | 5368.5 | 9505.0 | 50 |
| 52 | 9764.3 | 2730.4 | 5215.8 | 9326.1 | 9816.3 | 2773.1 | 5373.9 | 9511.2 | 52 |
| 54 | 9766.0 | 2731.8 | 5221.0 | 9332.2 | 9818.0 | 2774.6 | 5379.3 | 9517.5 | 54 |
| 56 | 9767.8 | 2733.3 | 5226.2 | 9338.3 | 9819.7 | 2776.0 | 5384.7 | 9523.8 | 56 |
| 58 | 9769.5 | 2734.7 | 5231.4 | 9344.4 | 9821.4 | 2777.4 | 5390.0 | 9530.0 | 58 |
| 60 | 9771.3 | 2736.1 | 5236.6 | 9350.5 | 9823.1 | 2778.8 | 5395.4 | 9536.3 | 60 |

## TABLE IX*a*.—CORRECTION FACTORS FOR USE WITH TABLE OF FUNCTIONS OF A 1° CURVE

Let $n$ = number of chord lengths used per degree of curve. $n=1$ when $c=100$ ft.; $n=2$ when $c=50$ ft. $n=4$ when $=25$ ft.; $n=10$ when $c=10$ ft.

Let $(f\tfrac{1}{2}I)=\sin\tfrac{1}{2}I$, $\operatorname{vers}\tfrac{1}{2}I$, $\operatorname{exsec}\tfrac{1}{2}I$ or $\tan\tfrac{1}{2}I$, according as the true *L.C.*, *M*, *E* or *T* is wanted for the particular value of $c$ used.

$$R(f\tfrac{1}{2}I)=\frac{\dfrac{100}{2n}}{\sin\tfrac{1}{2}\dfrac{D}{n}}(f\tfrac{1}{2}I)=(1+k)\frac{5730}{D}(f\tfrac{1}{2}I).$$

From which $$1+k=\frac{\dfrac{100}{2n}D}{5730\sin\tfrac{1}{2}\dfrac{D}{n}}.$$

$$\text{True } L.C.,\ M.E,\text{ or } T=\frac{\text{Tabular function}}{\text{Degree of curve}}(1+k).$$

| Degree of Curve. | Values of $k$ for Chord Lengths of | | | | Degree of Curve. |
|---|---|---|---|---|---|
| | 100 Feet. | 50 Feet. | 25 Feet. | 10 Feet. | |
| 0° 30′ | −0.000070 | −0.000073 | −0.000073 | −0.000074 | 0° 30′ |
| 1 0 | −0.000060 | −0.000070 | −0.000073 | −0.000074 | 1 0 |
| 1 30 | −0.000045 | −0.000066 | −0.000072 | −0.000074 | 1 30 |
| 2 0 | −0.000023 | −0.000061 | −0.000070 | −0.000074 | 2 0 |
| 2 30 | +0.000009 | −0.000055 | −0.000068 | −0.000074 | 2 30 |
| 3 0 | +0.00004 | −0.000045 | −0.000066 | −0.000073 | 3 0 |
| 3 30 | +0.00008 | −0.000035 | −0.000063 | −0.000073 | 3 30 |
| 4 0 | +0.00013 | −0.000023 | −0.000061 | −0.000072 | 4 0 |
| 4 30 | +0.00018 | −0.000010 | −0.000057 | −0.000072 | 4 30 |
| 5 0 | +0.00024 | −0.000006 | −0.000054 | −0.000071 | 5 0 |
| 5 30 | +0.00031 | +0.000022 | −0.000050 | −0.000071 | 5 30 |
| 6 0 | +0.00038 | +0.00004 | −0.000045 | −0.000070 | 6 0 |
| 6 30 | +0.00047 | +0.00006 | −0.000040 | −0.000069 | 6 30 |
| 7 0 | +0.00057 | +0.00008 | −0.000035 | −0.000068 | 7 0 |
| 7 30 | +0.00066 | +0.00011 | −0.000029 | −0.000067 | 7 30 |
| 8 0 | +0.00074 | +0.00014 | −0.000023 | −0.000066 | 8 0 |
| 8 30 | +0.00084 | +0.00016 | −0.000016 | −0.000065 | 8 30 |
| 9 0 | +0.00095 | +0.00019 | −0.000010 | −0.000064 | 9 0 |
| 9 30 | +0.00107 | +0.00021 | 0.00000 | −0.000063 | 9 30 |
| 10 0 | +0.00120 | +0.00024 | +0.00001 | −0.000062 | 10 0 |
| 11 0 | +0.00146 | +0.00031 | +0.00002 | −0.000059 | 11 0 |
| 12 0 | +0.00176 | +0.00038 | +0.00004 | −0.000056 | 12 0 |
| 13 0 | +0.00207 | +0.00046 | +0.00006 | −0.000053 | 13 0 |
| 14 0 | +0.00242 | +0.00055 | +0.00008 | −0.000050 | 14 0 |
| 15 0 | +0.00280 | +0.00064 | +0.00010 | −0.000046 | 15 0 |
| 16 0 | +0.00318 | +0.00074 | +0.00013 | −0.000042 | 16 0 |
| 17 0 | +0.00361 | +0.00085 | +0.00015 | −0.000038 | 17 0 |
| 18 0 | +0.00405 | +0.00096 | +0.00018 | −0.000033 | 18 0 |
| 19 0 | +0.00453 | +0.00108 | +0.00021 | −0.000028 | 19 0 |
| 20 0 | +0.00502 | +0.00120 | +0.00024 | −0.000023 | 20 0 |
| 21 0 | +0.00555 | +0.00133 | +0.00028 | −0.000018 | 21 0 |
| 22 0 | +0.00610 | +0.00146 | +0.00031 | −0.000013 | 22 0 |
| 23 0 | +0.00667 | +0.00161 | +0.00035 | −0.000007 | 23 0 |
| 24 0 | +0.00727 | +0.00176 | +0.00038 | −0.000001 | 24 0 |
| 25 0 | +0.00790 | +0.00192 | +0.00042 | +0.000005 | 25 0 |
| 26 0 | +0.00856 | +0.00207 | +0.00046 | +0.000011 | 26 0 |
| 27 0 | +0.00924 | +0.00224 | +0.00050 | +0.000018 | 27 0 |
| 28 0 | +0.00995 | +0.00242 | +0.00055 | +0.000025 | 28 0 |
| 29 0 | +0.01068 | +0.00260 | +0.00059 | +0.000032 | 29 0 |
| 30 0 | +0.01144 | +0.00279 | +0.00064 | +0.000040 | 30 0 |

| ′ | 0° | | 1° | | 2° | | 3° | | 4° | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .00000 | One. | .01745 | .99985 | .03490 | .99939 | .05234 | .99863 | .06976 | .99756 | 60 |
| 1 | .00029 | One. | .01774 | .99984 | .03519 | .99938 | .05263 | .99861 | .07005 | .99754 | 59 |
| 2 | .00058 | One. | .01803 | .99984 | .03548 | .99937 | .05292 | .99860 | .07034 | .99752 | 58 |
| 3 | .00087 | One. | .01832 | .99983 | .03577 | .99936 | .05321 | .99858 | .07063 | .99750 | 57 |
| 4 | .00116 | One. | .01862 | .99983 | .03606 | .99935 | .05350 | .99857 | .07092 | .99748 | 56 |
| 5 | .00145 | One. | .01891 | .99982 | .03635 | .99934 | .05379 | .99855 | .07121 | .99746 | 55 |
| 6 | .00175 | One. | .01920 | .99982 | .03664 | .99933 | .05408 | .99854 | .07150 | .99744 | 54 |
| 7 | .00204 | One. | .01949 | .99981 | .03693 | .99932 | .05437 | .99852 | .07179 | .99742 | 53 |
| 8 | .00233 | One. | .01978 | .99980 | .03723 | .99931 | .05466 | .99851 | .07208 | .99740 | 52 |
| 9 | .00262 | One. | .02007 | .99980 | .03752 | .99930 | .05495 | .99849 | .07237 | .99738 | 51 |
| 10 | .00291 | One. | .02036 | .99979 | .03781 | .99929 | .05524 | .99847 | .07266 | .99736 | 50 |
| 11 | .00320 | .99999 | .02065 | .99979 | .03810 | .99927 | .05553 | .99846 | .07295 | .99734 | 49 |
| 12 | .00349 | .99999 | .02094 | .99978 | .03839 | .99926 | .05582 | .99844 | .07324 | .99731 | 48 |
| 13 | .00378 | .99999 | .02123 | .99977 | .03868 | .99925 | .05611 | .99842 | .07353 | .99729 | 47 |
| 14 | .00407 | .99999 | .02152 | .99977 | .03897 | .99924 | .05640 | .99841 | .07382 | .99727 | 46 |
| 15 | .00436 | .99999 | .02181 | .99976 | .03926 | .99923 | .05669 | .99839 | .07411 | .99725 | 45 |
| 16 | .00465 | .99999 | .02211 | .99976 | .03955 | .99922 | .05698 | .99838 | .07440 | .99723 | 44 |
| 17 | .00495 | .99999 | .02240 | .99975 | .03984 | .99921 | .05727 | .99836 | .07469 | .99721 | 43 |
| 18 | .00524 | .99999 | .02269 | .99974 | .04013 | .99919 | .05756 | .99834 | .07498 | .99719 | 42 |
| 19 | .00553 | .99998 | .02298 | .99974 | .04042 | .99918 | .05785 | .99833 | .07527 | .99716 | 41 |
| 20 | .00582 | .99998 | .02327 | .99973 | .04071 | .99917 | .05814 | .99831 | .07556 | .99714 | 40 |
| 21 | .00611 | .99998 | .02356 | .99972 | .04100 | .99916 | .05844 | .99829 | .07585 | .99712 | 39 |
| 22 | .00640 | .99998 | .02385 | .99972 | .04129 | .99915 | .05873 | .99827 | .07614 | .99710 | 38 |
| 23 | .00669 | .99998 | .02414 | .99971 | .04159 | .99913 | .05902 | .99826 | .07643 | .99708 | 37 |
| 24 | .00698 | .99998 | .02443 | .99970 | .04188 | .99912 | .05931 | .99824 | .07672 | .99705 | 36 |
| 25 | .00727 | .99997 | .02472 | .99969 | .04217 | .99911 | .05960 | .99822 | .07701 | .99703 | 35 |
| 26 | .00756 | .99997 | .02501 | .99969 | .04246 | .99910 | .05989 | .99821 | .07730 | .99701 | 34 |
| 27 | .00785 | .99997 | .02530 | .99968 | .04275 | .99909 | .06018 | .99819 | .07759 | .99699 | 33 |
| 28 | .00814 | .99997 | .02560 | .99967 | .04304 | .99907 | .06047 | .99817 | .07788 | .99696 | 32 |
| 29 | .00844 | .99996 | .02589 | .99966 | .04333 | .99906 | .06076 | .99815 | .07817 | .99694 | 31 |
| 30 | .00873 | .99996 | .02618 | .99966 | .04362 | .99905 | .06105 | .99813 | .07846 | .99692 | 30 |
| 31 | .00902 | .99996 | .02647 | .99965 | .04391 | .99904 | .06134 | .99812 | .07875 | .99689 | 29 |
| 32 | .00931 | .99996 | .02676 | .99964 | .04420 | .99902 | .06163 | .99810 | .07904 | .99687 | 28 |
| 33 | .00960 | .99995 | .02705 | .99963 | .04449 | .99901 | .06192 | .99808 | .07933 | .99685 | 27 |
| 34 | .00989 | .99995 | .02734 | .99963 | .04478 | .99900 | .06221 | .99806 | .07962 | .99683 | 26 |
| 35 | .01018 | .99995 | .02763 | .99962 | .04507 | .99898 | .06250 | .99804 | .07991 | .99680 | 25 |
| 36 | .01047 | .99995 | .02792 | .99961 | .04536 | .99897 | .06279 | .99803 | .08020 | .99678 | 24 |
| 37 | .01076 | .99994 | .02821 | .99960 | .04565 | .99896 | .06308 | .99801 | .08049 | .99676 | 23 |
| 38 | .01105 | .99994 | .02850 | .99959 | .04594 | .99894 | .06337 | .99799 | .08078 | .99673 | 22 |
| 39 | .01134 | .99994 | .02879 | .99959 | .04623 | .99893 | .06366 | .99797 | .08107 | .99671 | 21 |
| 40 | .01164 | .99993 | .02908 | .99958 | .04653 | .99892 | .06395 | .99795 | .08136 | .99668 | 20 |
| 41 | .01193 | .99993 | .02938 | .99957 | .04682 | .99890 | .06424 | .99793 | .08165 | .99666 | 19 |
| 42 | .01222 | .99993 | .02967 | .99956 | .04711 | .99889 | .06453 | .99792 | .08194 | .99664 | 18 |
| 43 | .01251 | .99992 | .02996 | .99955 | .04740 | .99888 | .06482 | .99790 | .08223 | .99661 | 17 |
| 44 | .01280 | .99992 | .03025 | .99954 | .04769 | .99886 | .06511 | .99788 | .08252 | .99659 | 16 |
| 45 | .01309 | .99991 | .03054 | .99953 | .04798 | .99885 | .06540 | .99786 | .08281 | .99657 | 15 |
| 46 | .01338 | .99991 | .03083 | .99952 | .04827 | .99883 | .06569 | .99784 | .08310 | .99654 | 14 |
| 47 | .01367 | .99991 | .03112 | .99952 | .04856 | .99882 | .06598 | .99782 | .08339 | .99652 | 13 |
| 48 | .01396 | .99990 | .03141 | .99951 | .04885 | .99881 | .06627 | .99780 | .08368 | .99649 | 12 |
| 49 | .01425 | .99990 | .03170 | .99950 | .04914 | .99879 | .06656 | .99778 | .08397 | .99647 | 11 |
| 50 | .01454 | .99989 | .03199 | .99949 | .04943 | .99878 | .06685 | .99776 | .08426 | .99644 | 10 |
| 51 | .01483 | .99989 | .03228 | .99948 | .04972 | .99876 | .06714 | .99774 | .08455 | .99642 | 9 |
| 52 | .01513 | .99989 | .03257 | .99947 | .05001 | .99875 | .06743 | .99772 | .08484 | .99639 | 8 |
| 53 | .01542 | .99988 | .03286 | .99946 | .05030 | .99873 | .06773 | .99770 | .08513 | .99637 | 7 |
| 54 | .01571 | .99988 | .03316 | .99945 | .05059 | .99872 | .06802 | .99768 | .08542 | .99635 | 6 |
| 55 | .01600 | .99987 | .03345 | .99944 | .05088 | .99870 | .06831 | .99766 | .08571 | .99632 | 5 |
| 56 | .01629 | .99987 | .03374 | .99943 | .05117 | .99869 | .06860 | .99764 | .08600 | .99630 | 4 |
| 57 | .01658 | .99986 | .03403 | .99942 | .05146 | .99867 | .06889 | .99762 | .08629 | .99627 | 3 |
| 58 | .01687 | .99986 | .03432 | .99941 | .05175 | .99866 | .06918 | .99760 | .08658 | .99625 | 2 |
| 59 | .01716 | .99985 | .03461 | .99940 | .05205 | .99864 | .06947 | .99758 | .08687 | .99622 | 1 |
| 60 | .01745 | .99985 | .03490 | .99939 | .05234 | .99863 | .06976 | .99756 | .08716 | .99619 | 0 |
| | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| ′ | 89° | | 88° | | 87° | | 86° | | 85° | | |

| ′ | 5° | | 6° | | 7° | | 8° | | 9° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .08716 | .99619 | .10453 | .99452 | .12187 | .99255 | .13917 | .99027 | .15643 | .98769 | 60 |
| 1 | .08745 | .99617 | .10482 | .99449 | .12216 | .99251 | .13946 | .99023 | .15672 | .98764 | 59 |
| 2 | .08774 | .99614 | .10511 | .99446 | .12245 | .99248 | .13975 | .99019 | .15701 | .98760 | 58 |
| 3 | .08803 | .99612 | .10540 | .99443 | .12274 | .99244 | .14004 | .99015 | .15730 | .98755 | 57 |
| 4 | .08831 | .99609 | .10569 | .99440 | .12302 | .99240 | .14033 | .99011 | .15758 | .98751 | 56 |
| 5 | .08860 | .99607 | .10597 | .99437 | .12331 | .99237 | .14061 | .99006 | .15787 | .98746 | 55 |
| 6 | .08889 | .99604 | .10626 | .99434 | .12360 | .99233 | .14090 | .99002 | .15816 | .98741 | 54 |
| 7 | .08918 | .99602 | .10655 | .99431 | .12389 | .99230 | .14119 | .98998 | .15845 | .98737 | 53 |
| 8 | .08947 | .99599 | .10684 | .99428 | .12418 | .99226 | .14148 | .98994 | .15873 | .98732 | 52 |
| 9 | .08976 | .99596 | .10713 | .99424 | .12447 | .99222 | .14177 | .98990 | .15902 | .98728 | 51 |
| 10 | .09005 | .99594 | .10742 | .99421 | .12476 | .99219 | .14205 | .98986 | .15931 | .98723 | 50 |
| 11 | .09034 | .99591 | .10771 | .99418 | .12504 | .99215 | .14234 | .98982 | .15959 | .98718 | 49 |
| 12 | .09063 | .99588 | .10800 | .99415 | .12533 | .99211 | .14263 | .98978 | .15988 | .98714 | 48 |
| 13 | .09092 | .99586 | .10829 | .99412 | .12562 | .99208 | .14292 | .98973 | .16017 | .98709 | 47 |
| 14 | .09121 | .99583 | .10858 | .99409 | .12591 | .99204 | .14320 | .98969 | .16046 | .98704 | 46 |
| 15 | .09150 | .99580 | .10887 | .99406 | .12620 | .99200 | .14349 | .98965 | .16074 | .98700 | 45 |
| 16 | .09179 | .99578 | .10916 | .99402 | .12649 | .99197 | .14378 | .98961 | .16103 | .98695 | 44 |
| 17 | .09208 | .99575 | .10945 | .99399 | .12678 | .99193 | .14407 | .98957 | .16132 | .98690 | 43 |
| 18 | .09237 | .99572 | .10973 | .99396 | .12706 | .99189 | .14436 | .98953 | .16160 | .98686 | 42 |
| 19 | .09266 | .99570 | .11002 | .99393 | .12735 | .99186 | .14464 | .98948 | .16189 | .98681 | 41 |
| 20 | .09295 | .99567 | .11031 | .99390 | .12764 | .99182 | .14493 | .98944 | .16218 | .98676 | 40 |
| 21 | .09324 | .99564 | .11060 | .99386 | .12793 | .99178 | .14522 | .98940 | .16246 | .98671 | 39 |
| 22 | .09353 | .99562 | .11089 | .99383 | .12822 | .99175 | .14551 | .98936 | .16275 | .98667 | 38 |
| 23 | .09382 | .99559 | .11118 | .99380 | .12851 | .99171 | .14580 | .98931 | .16304 | .98662 | 37 |
| 24 | .09411 | .99556 | .11147 | .99377 | .12880 | .99167 | .14608 | .98927 | .16333 | .98657 | 36 |
| 25 | .09440 | .99553 | .11176 | .99374 | .12908 | .99163 | .14637 | .98923 | .16361 | .98652 | 35 |
| 26 | .09469 | .99551 | .11205 | .99370 | .12937 | .99160 | .14666 | .98919 | .16390 | .98648 | 34 |
| 27 | .09498 | .99548 | .11234 | .99367 | .12966 | .99156 | .14695 | .98914 | .16419 | .98643 | 33 |
| 28 | .09527 | .99545 | .11263 | .99364 | .12995 | .99152 | .14723 | .98910 | .16447 | .98638 | 32 |
| 29 | .09556 | .99542 | .11291 | .99360 | .13024 | .99148 | .14752 | .98906 | .16476 | .98633 | 31 |
| 30 | .09585 | .99540 | .11320 | .99357 | .13053 | .99144 | .14781 | .98902 | .16505 | .98629 | 30 |
| 31 | .09614 | .99537 | .11349 | .99354 | .13081 | .99141 | .14810 | .98897 | .16533 | .98624 | 29 |
| 32 | .09642 | .99534 | .11378 | .99351 | .13110 | .99137 | .14838 | .98893 | .16562 | .98619 | 28 |
| 33 | .09671 | .99531 | .11407 | .99347 | .13139 | .99133 | .14867 | .98889 | .16591 | .98614 | 27 |
| 34 | .09700 | .99528 | .11436 | .99344 | .13168 | .99129 | .14896 | .98884 | .16620 | .98609 | 26 |
| 35 | .09729 | .99526 | .11465 | .99341 | .13197 | .99125 | .14925 | .98880 | .16648 | .98604 | 25 |
| 36 | .09758 | .99523 | .11494 | .99337 | .13226 | .99122 | .14954 | .98876 | .16677 | .98600 | 24 |
| 37 | .09787 | .99520 | .11523 | .99334 | .13254 | .99118 | .14982 | .98871 | .16706 | .98595 | 23 |
| 38 | .09816 | .99517 | .11552 | .99331 | .13283 | .99114 | .15011 | .98867 | .16734 | .98590 | 22 |
| 39 | .09845 | .99514 | .11580 | .99327 | .13312 | .99110 | .15040 | .98863 | .16763 | .98585 | 21 |
| 40 | .09874 | .99511 | .11609 | .99324 | .13341 | .99106 | .15069 | .98858 | .16792 | .98580 | 20 |
| 41 | .09903 | .99508 | .11638 | .99320 | .13370 | .99102 | .15097 | .98854 | .16820 | .98575 | 19 |
| 42 | .09932 | .99506 | .11667 | .99317 | .13399 | .99098 | .15126 | .98849 | .16849 | .98570 | 18 |
| 43 | .09961 | .99503 | .11696 | .99314 | .13427 | .99094 | .15155 | .98845 | .16878 | .98565 | 17 |
| 44 | .09990 | .99500 | .11725 | .99310 | .13456 | .99091 | .15184 | .98841 | .16906 | .98561 | 16 |
| 45 | .10019 | .99497 | .11754 | .99307 | .13485 | .99087 | .15212 | .98836 | .16935 | .98556 | 15 |
| 46 | .10048 | .99494 | .11783 | .99303 | .13514 | .99083 | .15241 | .98832 | .16964 | .98551 | 14 |
| 47 | .10077 | .99491 | .11812 | .99300 | .13543 | .99079 | .15270 | .98827 | .16992 | .98546 | 13 |
| 48 | .10106 | .99488 | .11840 | .99297 | .13572 | .99075 | .15299 | .98823 | .17021 | .98541 | 12 |
| 49 | .10135 | .99485 | .11869 | .99293 | .13600 | .99071 | .15327 | .98818 | .17050 | .98536 | 11 |
| 50 | .10164 | .99482 | .11898 | .99290 | .13629 | .99067 | .15356 | .98814 | .17078 | .98531 | 10 |
| 51 | .10192 | .99479 | .11927 | .99286 | .13658 | .99063 | .15385 | .98809 | .17107 | .98526 | 9 |
| 52 | .10221 | .99476 | .11956 | .99283 | .13687 | .99059 | .15414 | .98805 | .17136 | .98521 | 8 |
| 53 | .10250 | .99473 | .11985 | .99279 | .13716 | .99055 | .15442 | .98800 | .17164 | .98516 | 7 |
| 54 | .10279 | .99470 | .12014 | .99276 | .13744 | .99051 | .15471 | .98796 | .17193 | .98511 | 6 |
| 55 | .10308 | .99467 | .12043 | .99272 | .13773 | .99047 | .15500 | .98791 | .17222 | .98506 | 5 |
| 56 | .10337 | .99464 | .12071 | .99269 | .13802 | .99043 | .15529 | .98787 | .17250 | .98501 | 4 |
| 57 | 10366 | .99461 | .12100 | .99265 | .13831 | .99039 | .15557 | .98782 | .17279 | .98496 | 3 |
| 58 | .10395 | .99458 | .12129 | .99262 | .13860 | .99035 | .15586 | .98778 | .17308 | .98491 | 2 |
| 59 | .10424 | .99455 | .12158 | .99258 | .13889 | .99031 | .15615 | .98773 | .17336 | .98486 | 1 |
| 60 | .10453 | .99452 | .12187 | .99255 | .13917 | .99027 | .15643 | .98769 | .17365 | .98481 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 84° | | 83° | | 82° | | 81° | | 80° | | |

| ′ | 10° | | 11° | | 12° | | 13° | | 14° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .17365 | .98481 | .19081 | .98163 | .20791 | .97815 | .22495 | .97437 | .24192 | .97030 | 60 |
| 1 | .17393 | .98476 | .19109 | .98157 | .20820 | .97809 | .22523 | .97430 | .24220 | .97023 | 59 |
| 2 | .17422 | .98471 | .19138 | .98152 | .20848 | .97803 | .22552 | .97424 | .24249 | .97015 | 58 |
| 3 | .17451 | .98466 | .19167 | .98146 | .20877 | .97797 | .22580 | .97417 | .24277 | .97008 | 57 |
| 4 | .17479 | .98461 | .19195 | .98140 | .20905 | .97791 | .22608 | .97411 | .24305 | .97001 | 56 |
| 5 | .17508 | .98455 | .19224 | .98135 | .20933 | .97784 | .22637 | .97404 | .24333 | .96994 | 55 |
| 6 | .17537 | .98450 | .19252 | .98129 | .20962 | .97778 | .22665 | .97398 | .24362 | .96987 | 54 |
| 7 | .17565 | .98445 | .19281 | .98124 | .20990 | .97772 | .22693 | .97391 | .24390 | .96980 | 53 |
| 8 | .17594 | .98440 | .19309 | .98118 | .21019 | .97766 | .22722 | .97384 | .24418 | .96973 | 52 |
| 9 | .17623 | .98435 | .19338 | .98112 | .21047 | .97760 | .22750 | .97378 | .24446 | .96966 | 51 |
| 10 | .17651 | .98430 | .19366 | .98107 | .21076 | .97754 | .22778 | .97371 | .24474 | .96959 | 50 |
| 11 | .17680 | .98425 | .19395 | .98101 | .21104 | .97748 | .22807 | .97365 | .24503 | .96952 | 49 |
| 12 | .17708 | .98420 | .19423 | .98096 | .21132 | .97742 | .22835 | .97358 | .24531 | .96945 | 48 |
| 13 | .17737 | .98414 | .19452 | .98090 | .21161 | .97735 | .22863 | .97351 | .24559 | .96937 | 47 |
| 14 | .17766 | .98409 | .19481 | .98084 | .21189 | .97729 | .22892 | .97345 | .24587 | .96930 | 46 |
| 15 | .17794 | .98404 | .19509 | .98079 | .21218 | .97723 | .22920 | .97338 | .24615 | .96923 | 45 |
| 16 | .17823 | .98399 | .19538 | .98073 | .21246 | .97717 | .22948 | .97331 | .24644 | .96916 | 44 |
| 17 | .17852 | .98394 | .19566 | .98067 | .21275 | .97711 | .22977 | .97325 | .24672 | .96909 | 43 |
| 18 | .17880 | .98389 | .19595 | .98061 | .21303 | .97705 | .23005 | .97318 | .24700 | .96902 | 42 |
| 19 | .17909 | .98383 | .19623 | .98056 | .21331 | .97698 | .23033 | .97311 | .24728 | .96894 | 41 |
| 20 | .17937 | .98378 | .19652 | .98050 | .21360 | .97692 | .23062 | .97304 | .24756 | .96887 | 40 |
| 21 | .17966 | .98373 | .19680 | .98044 | .21388 | .97686 | .23090 | .97298 | .24784 | .96880 | 39 |
| 22 | .17995 | .98368 | .19709 | .98039 | .21417 | .97680 | .23118 | .97291 | .24813 | .96873 | 38 |
| 23 | .18023 | .98362 | .19737 | .98033 | .21445 | .97673 | .23146 | .97284 | .24841 | .96866 | 37 |
| 24 | .18052 | .98357 | .19766 | .98027 | .21474 | .97667 | .23175 | .97278 | .24869 | .96858 | 36 |
| 25 | .18081 | .98352 | .19794 | .98021 | .21502 | .97661 | .23203 | .97271 | .24897 | .96851 | 35 |
| 26 | .18109 | .98347 | .19823 | .98016 | .21530 | .97655 | .23231 | .97264 | .24925 | .96844 | 34 |
| 27 | .18138 | .98341 | .19851 | .98010 | .21559 | .97648 | .23260 | .97257 | .24954 | .96837 | 33 |
| 28 | .18166 | .98336 | .19880 | .98004 | .21587 | .97642 | .23288 | .97251 | .24982 | .96829 | 32 |
| 29 | .18195 | .98331 | .19908 | .97998 | .21616 | .97636 | .23316 | .97244 | .25010 | .96822 | 31 |
| 30 | .18224 | .98325 | .19937 | .97992 | .21644 | .97630 | .23345 | .97237 | .25038 | .96815 | 30 |
| 31 | .18252 | .98320 | .19965 | .97987 | .21672 | .97623 | .23373 | .97230 | .25066 | .96807 | 29 |
| 32 | .18281 | .98315 | .19994 | .97981 | .21701 | .97617 | .23401 | .97223 | .25094 | .96800 | 28 |
| 33 | .18309 | .98310 | .20022 | .97975 | .21729 | .97611 | .23429 | .97217 | .25122 | .96793 | 27 |
| 34 | .18338 | .98304 | .20051 | .97969 | .21758 | .97604 | .23458 | .97210 | .25151 | .96786 | 26 |
| 35 | .18367 | .98299 | .20079 | .97963 | .21786 | .97598 | .23486 | .97203 | .25179 | .96778 | 25 |
| 36 | .18395 | .98294 | .20108 | .97958 | .21814 | .97592 | .23514 | .97196 | .25207 | .96771 | 24 |
| 37 | .18424 | .98288 | .20136 | .97952 | .21843 | .97585 | .23542 | .97189 | .25235 | .96764 | 23 |
| 38 | .18452 | .98283 | .20165 | .97946 | .21871 | .97579 | .23571 | .97182 | .25263 | .96756 | 22 |
| 39 | .18481 | .98277 | .20193 | .97940 | .21899 | .97573 | .23599 | .97176 | .25291 | .96749 | 21 |
| 40 | .18509 | .98272 | .20222 | .97934 | .21928 | .97566 | .23627 | .97169 | .25320 | .96742 | 20 |
| 41 | .18538 | .98267 | .20250 | .97928 | .21956 | .97560 | .23656 | .97162 | .25348 | .96734 | 19 |
| 42 | .18567 | .98261 | .20279 | .97922 | .21985 | .97553 | .23684 | .97155 | .25376 | .96727 | 18 |
| 43 | .18595 | .98256 | .20307 | .97916 | .22013 | .97547 | .23712 | .97148 | .25404 | .96719 | 17 |
| 44 | .18624 | .98250 | .20336 | .97910 | .22041 | .97541 | .23740 | .97141 | .25432 | .96712 | 16 |
| 45 | .18652 | .98245 | .20364 | .97905 | .22070 | .97534 | .23769 | .97134 | .25460 | .96705 | 15 |
| 46 | .18681 | .98240 | .20393 | .97899 | .22098 | .97528 | .23797 | .97127 | .25488 | .96697 | 14 |
| 47 | .18710 | .98234 | .20421 | .97893 | .22126 | .97521 | .23825 | .97120 | .25516 | .96690 | 13 |
| 48 | .18738 | .98229 | .20450 | .97887 | .22155 | .97515 | .23853 | .97113 | .25545 | .96682 | 12 |
| 49 | .18767 | .98223 | .20478 | .97881 | .22183 | .97508 | .23882 | .97106 | .25573 | .96675 | 11 |
| 50 | .18795 | .98218 | .20507 | .97875 | .22212 | .97502 | .23910 | .97100 | .25601 | .96667 | 10 |
| 51 | .18824 | .98212 | .20535 | .97869 | .22240 | .97496 | .23938 | .97093 | .25629 | .96660 | 9 |
| 52 | .18852 | .98207 | .20563 | .97863 | .22268 | .97489 | .23966 | .97086 | .25657 | .96653 | 8 |
| 53 | .18881 | .98201 | .20592 | .97857 | .22297 | .97483 | .23995 | .97079 | .25685 | .96645 | 7 |
| 54 | .18910 | .98196 | .20620 | .97851 | .22325 | .97476 | .24023 | .97072 | .25713 | .96638 | 6 |
| 55 | .18938 | .98190 | .20649 | .97845 | .22353 | .97470 | .24051 | .97065 | .25741 | .96630 | 5 |
| 56 | .18967 | .98185 | .20677 | .97839 | .22382 | .97463 | .24079 | .97058 | .25769 | .96623 | 4 |
| 57 | .18995 | .98179 | .20706 | .97833 | .22410 | .97457 | .24108 | .97051 | .25798 | .96615 | 3 |
| 58 | .19024 | .98174 | .20734 | .97827 | .22438 | .97450 | .24136 | .97044 | .25826 | .96608 | 2 |
| 59 | .19052 | .98168 | .20763 | .97821 | .22467 | .97444 | .24164 | .97037 | .25854 | .96600 | 1 |
| 60 | .19081 | .98163 | .20791 | .97815 | .22495 | .97437 | .24192 | .97030 | .25882 | .96593 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 79° | | 78° | | 77° | | 76° | | 75° | | |

| ′ | 15° | | 16° | | 17° | | 18° | | 19° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .25882 | .96593 | .27564 | .96126 | .29237 | .95630 | .30902 | .95106 | .32557 | .94552 | 60 |
| 1 | .25910 | .96585 | .27592 | .96118 | .29265 | .95622 | .30929 | .95097 | .32584 | .94542 | 59 |
| 2 | .25938 | .96578 | .27620 | .96110 | .29293 | .95613 | .30957 | .95088 | .32612 | .94533 | 58 |
| 3 | .25966 | .96570 | .27648 | .96102 | .29321 | .95605 | .30985 | .95079 | .32639 | .94523 | 57 |
| 4 | .25994 | .96562 | .27676 | .96094 | .29348 | .95596 | .31012 | .95070 | .32667 | .94514 | 56 |
| 5 | .26022 | .96555 | .27704 | .96086 | .29376 | .95588 | .31040 | .95061 | .32694 | .94504 | 55 |
| 6 | .26050 | .96547 | .27731 | .96078 | .29404 | .95579 | .31068 | .95052 | .32722 | .94495 | 54 |
| 7 | .26079 | .96540 | .27759 | .96070 | .29432 | .95571 | .31095 | .95043 | .32749 | .94485 | 53 |
| 8 | .26107 | .96532 | .27787 | .96062 | .29460 | .95562 | .31123 | .95033 | .32777 | .94476 | 52 |
| 9 | .26135 | .96524 | .27815 | .96054 | .29487 | .95554 | .31151 | .95024 | .32804 | .94466 | 51 |
| 10 | .26163 | .96517 | .27843 | .96046 | .29515 | .95545 | .31178 | .95015 | .32832 | .94457 | 50 |
| 11 | .26191 | .96509 | .27871 | .96037 | .29543 | .95536 | .31206 | .95006 | .32859 | .94447 | 49 |
| 12 | .26219 | .96502 | .27899 | .96029 | .29571 | .95528 | .31233 | .94997 | .32887 | .94438 | 48 |
| 13 | .26247 | .96494 | .27927 | .96021 | .29599 | .95519 | .31261 | .94988 | .32914 | .94428 | 47 |
| 14 | .26275 | .96486 | .27955 | .96013 | .29626 | .95511 | .31289 | .94979 | .32942 | .94418 | 46 |
| 15 | .26303 | .96479 | .27983 | .96005 | .29654 | .95502 | .31316 | .94970 | .32969 | .94409 | 45 |
| 16 | .26331 | .96471 | .28011 | .95997 | .29682 | .95493 | .31344 | .94961 | .32997 | .94399 | 44 |
| 17 | .26359 | .96463 | .28039 | .95989 | .29710 | .95485 | .31372 | .94952 | .33024 | .94390 | 43 |
| 18 | .26387 | .96456 | .28067 | .95981 | .29737 | .95476 | .31399 | .94943 | .33051 | .94380 | 42 |
| 19 | .26415 | .96448 | .28095 | .95972 | .29765 | .95467 | .31427 | .94933 | .33079 | .94370 | 41 |
| 20 | .26443 | .96440 | .28123 | .95964 | .29793 | .95459 | .31454 | .94924 | .33106 | .94361 | 40 |
| 21 | .26471 | .96433 | .28150 | .95956 | .29821 | .95450 | .31482 | .94915 | .33134 | .94351 | 39 |
| 22 | .26500 | .96425 | .28178 | .95948 | .29849 | .95441 | .31510 | .94906 | .33161 | .94342 | 38 |
| 23 | .26528 | .96417 | .28206 | .95940 | .29876 | .95433 | .31537 | .94897 | .33189 | .94332 | 37 |
| 24 | .26556 | .96410 | .28234 | .95931 | .29904 | .95424 | .31565 | .94888 | .33216 | .94322 | 36 |
| 25 | .26584 | .96402 | .28262 | .95923 | .29932 | .95415 | .31593 | .94878 | .33244 | .94313 | 35 |
| 26 | .26612 | .96394 | .28290 | .95915 | .29960 | .95407 | .31620 | .94869 | .33271 | .94303 | 34 |
| 27 | .26640 | .96386 | .28318 | .95907 | .29987 | .95398 | .31648 | .94860 | .33298 | .94293 | 33 |
| 28 | .26668 | .96379 | .28346 | .95898 | .30015 | .95389 | .31675 | .94851 | .33326 | .94284 | 32 |
| 29 | .26696 | .96371 | .28374 | .95890 | .30043 | .95380 | .31703 | .94842 | .33353 | .94274 | 31 |
| 30 | .26724 | .96363 | .28402 | .95882 | .30071 | .95372 | .31730 | .94832 | .33381 | .94264 | 30 |
| 31 | .26752 | .96355 | .28429 | .95874 | .30098 | .95363 | .31758 | .94823 | .33408 | .94254 | 29 |
| 32 | .26780 | .96347 | .28457 | .95865 | .30126 | .95354 | .31786 | .94814 | .33436 | .94245 | 28 |
| 33 | .26808 | .96340 | .28485 | .95857 | .30154 | .95345 | .31813 | .94805 | .33463 | .94235 | 27 |
| 34 | .26836 | .96332 | .28513 | .95849 | .30182 | .95337 | .31841 | .94795 | .33490 | .94225 | 26 |
| 35 | .26864 | .96324 | .28541 | .95841 | .30209 | .95328 | .31868 | .94786 | .33518 | .94215 | 25 |
| 36 | .26892 | .96316 | .28569 | .95832 | .30237 | .95319 | .31896 | .94777 | .33545 | .94206 | 24 |
| 37 | .26920 | .96308 | .28597 | .95824 | .30265 | .95310 | .31923 | .94768 | .33573 | .94196 | 23 |
| 38 | .26948 | .96301 | .28625 | .95816 | .30292 | .95301 | .31951 | .94758 | .33600 | .94186 | 22 |
| 39 | .26976 | .96293 | .28652 | .95807 | .30320 | .95293 | .31979 | .94749 | .33627 | .94176 | 21 |
| 40 | .27004 | .96285 | .28680 | .95799 | .30348 | .95284 | .32006 | .94740 | .33655 | .94167 | 20 |
| 41 | .27032 | .96277 | .28708 | .95791 | .30376 | .95275 | .32034 | .94730 | .33682 | .94157 | 19 |
| 42 | .27060 | .96269 | .28736 | .95782 | .30403 | .95266 | .32061 | .94721 | .33710 | .94147 | 18 |
| 43 | .27088 | .96261 | .28764 | .95774 | .30431 | .95257 | .32089 | .94712 | .33737 | .94137 | 17 |
| 44 | .27116 | .96253 | .28792 | .95766 | .30459 | .95248 | .32116 | .94702 | .33764 | .94127 | 16 |
| 45 | .27144 | .96246 | .28820 | .95757 | .30486 | .95240 | .32144 | .94693 | .33792 | .94118 | 15 |
| 46 | .27172 | .96238 | .28847 | .95749 | .30514 | .95231 | .32171 | .94684 | .33819 | .94108 | 14 |
| 47 | .27200 | .96230 | .28875 | .95740 | .30542 | .95222 | .32199 | .94674 | .33846 | .94098 | 13 |
| 48 | .27228 | .96222 | .28903 | .95732 | .30570 | .95213 | .32227 | .94665 | .33874 | .94088 | 12 |
| 49 | .27256 | .96214 | .28931 | .95724 | .30597 | .95204 | .32254 | .94656 | .33901 | .94078 | 11 |
| 50 | .27284 | .96206 | .28959 | .95715 | .30625 | .95195 | .32282 | .94646 | .33929 | .94068 | 10 |
| 51 | .27312 | .96198 | .28987 | .95707 | .30653 | .95186 | .32309 | .94637 | .33956 | .94058 | 9 |
| 52 | .27340 | .96190 | .29015 | .95698 | .30680 | .95177 | .32337 | .94627 | .33983 | .94049 | 8 |
| 53 | .27368 | .96182 | .29042 | .95690 | .30708 | .95168 | .32364 | .94618 | .34011 | .94039 | 7 |
| 54 | .27396 | .96174 | .29070 | .95681 | .30736 | .95159 | .32392 | .94609 | .34038 | .94029 | 6 |
| 55 | .27424 | .96166 | .29098 | .95673 | .30763 | .95150 | .32419 | .94599 | .34065 | .94019 | 5 |
| 56 | .27452 | .96158 | .29126 | .95664 | .30791 | .95142 | .32447 | .94590 | .34093 | .94009 | 4 |
| 57 | .27480 | .96150 | .29154 | .95656 | .30819 | .95133 | .32474 | .94580 | .34120 | .93999 | 3 |
| 58 | .27508 | .96142 | .29182 | .95647 | .30846 | .95124 | .32502 | .94571 | .34147 | .93989 | 2 |
| 59 | .27536 | .96134 | .29209 | .95639 | .30874 | .95115 | .32529 | .94561 | .34175 | .93979 | 1 |
| 60 | .27564 | .96126 | .29237 | .95630 | .30902 | .95106 | .32557 | .94552 | .34202 | .93969 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 74° | | 73° | | 72° | | 71° | | 70° | | |

## TABLE X.—SINES AND COSINES.

| ′ | 20° | | 21° | | 22° | | 23° | | 24° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .34202 | .93969 | .35837 | .93358 | .37461 | .92718 | .39073 | .92050 | .40674 | .91355 | 60 |
| 1 | .34229 | .93959 | .35864 | .93348 | .37488 | .92707 | .39100 | .92039 | .40700 | .91343 | 59 |
| 2 | .34257 | .93949 | .35891 | .93337 | .37515 | .92697 | .39127 | .92028 | .40727 | .91331 | 58 |
| 3 | .34284 | .93939 | .35918 | .93327 | .37542 | .92686 | .39153 | .92016 | .40753 | .91319 | 57 |
| 4 | .34311 | .93929 | .35945 | .93316 | .37569 | .92675 | .39180 | .92005 | .40780 | .91307 | 56 |
| 5 | .34339 | .93919 | .35973 | .93306 | .37595 | .92664 | .39207 | .91994 | .40806 | .91295 | 55 |
| 6 | .34366 | .93909 | .36000 | .93295 | .37622 | .92653 | .39234 | .91982 | .40833 | .91283 | 54 |
| 7 | .34393 | .93899 | .36027 | .93285 | .37649 | .92642 | .39260 | .91971 | .40860 | .91272 | 53 |
| 8 | .34421 | .93889 | .36054 | .93274 | .37676 | .92631 | .39287 | .91959 | .40886 | .91260 | 52 |
| 9 | .34448 | .93879 | .36081 | .93264 | .37703 | .92620 | .39314 | .91948 | .40913 | .91248 | 51 |
| 10 | .34475 | .93869 | .36108 | .93253 | .37730 | .92609 | .39341 | .91936 | .40939 | .91236 | 50 |
| 11 | .34503 | .93859 | .36135 | .93243 | .37757 | .92598 | .39367 | .91925 | .40966 | .91224 | 49 |
| 12 | .34530 | .93849 | .36162 | .93232 | .37784 | .92587 | .39394 | .91914 | .40992 | .91212 | 48 |
| 13 | .34557 | .93839 | .36190 | .93222 | .37811 | .92576 | .39421 | .91902 | .41019 | .91200 | 47 |
| 14 | .34584 | .93829 | .36217 | .93211 | .37838 | .92565 | .39448 | .91891 | .41045 | .91188 | 46 |
| 15 | .34612 | .93819 | .36244 | .93201 | .37865 | .92554 | .39474 | .91879 | .41072 | .91176 | 45 |
| 16 | .34639 | .93809 | .36271 | .93190 | .37892 | .92543 | .39501 | .91868 | .41098 | .91164 | 44 |
| 17 | .34666 | .93799 | .36298 | .93180 | .37919 | .92532 | .39528 | .91856 | .41125 | .91152 | 43 |
| 18 | .34694 | .93789 | .36325 | .93169 | .37946 | .92521 | .39555 | .91845 | .41151 | .91140 | 42 |
| 19 | .34721 | .93779 | .36352 | .93159 | .37973 | .92510 | .39581 | .91833 | .41178 | .91128 | 41 |
| 20 | .34748 | .93769 | .36379 | .93148 | .37999 | .92499 | .39608 | .91822 | .41204 | .91116 | 40 |
| 21 | .34775 | .93759 | .36406 | .93137 | .38026 | .92488 | .39635 | .91810 | .41231 | .91104 | 39 |
| 22 | .34803 | .93748 | .36434 | .93127 | .38053 | .92477 | .39661 | .91799 | .41257 | .91092 | 38 |
| 23 | .34830 | .93738 | .36461 | .93116 | .38080 | .92466 | .39688 | .91787 | .41284 | .91080 | 37 |
| 24 | .34857 | .93728 | .36488 | .93106 | .38107 | .92455 | .39715 | .91775 | .41310 | .91068 | 36 |
| 25 | .34884 | .93718 | .36515 | .93095 | .38134 | .92444 | .39741 | .91764 | .41337 | .91056 | 35 |
| 26 | .34912 | .93708 | .36542 | .93084 | .38161 | .92432 | .39768 | .91752 | .41363 | .91044 | 34 |
| 27 | .34939 | .93698 | .36569 | .93074 | .38188 | .92421 | .39795 | .91741 | .41390 | .91032 | 33 |
| 28 | .34966 | .93688 | .36596 | .93063 | .38215 | .92410 | .39822 | .91729 | .41416 | .91020 | 32 |
| 29 | .34993 | .93677 | .36623 | .93052 | .38241 | .92399 | .39848 | .91718 | .41443 | .91008 | 31 |
| 30 | .35021 | .93667 | .36650 | .93042 | .38268 | .92388 | .39875 | .91706 | .41469 | .90996 | 30 |
| 31 | .35048 | .93657 | .36677 | .93031 | .38295 | .92377 | .39902 | .91694 | .41496 | .90984 | 29 |
| 32 | .35075 | .93647 | .36704 | .93020 | .38322 | .92366 | .39928 | .91688 | .41522 | .90972 | 28 |
| 33 | .35102 | .93637 | .36731 | .93010 | .38349 | .92355 | .39955 | .91671 | .41549 | .90960 | 27 |
| 34 | .35130 | .93626 | .36758 | .92999 | .38376 | .92343 | .39982 | .91660 | .41575 | .90948 | 26 |
| 35 | .35157 | .93616 | .36785 | .92988 | .38403 | .92332 | .40008 | .91648 | .41602 | .90936 | 25 |
| 36 | .35184 | .93606 | .36812 | .92978 | .38430 | .92321 | .40035 | .91636 | .41628 | .90924 | 24 |
| 37 | .35211 | .93596 | .36839 | .92967 | .38456 | .92310 | .40062 | .91625 | .41655 | .90911 | 23 |
| 38 | .35239 | .93585 | .36867 | .92956 | .38483 | .92299 | .40088 | .91613 | .41681 | .90899 | 22 |
| 39 | .35266 | .93575 | .36894 | .92945 | .38510 | .92287 | .40115 | .91601 | .41707 | .90887 | 21 |
| 40 | .35293 | .93565 | .36921 | .92935 | .38537 | .92276 | .40141 | .91590 | .41734 | .90875 | 20 |
| 41 | .35320 | .93555 | .36948 | .92924 | .38564 | .92265 | .40168 | .91578 | .41760 | .90863 | 19 |
| 42 | .35347 | .93544 | .36975 | .92913 | .38591 | .92254 | .40195 | .91566 | .41787 | .90851 | 18 |
| 43 | .35375 | .93534 | .37002 | .92902 | .38617 | .92243 | .40221 | .91555 | .41813 | .90839 | 17 |
| 44 | .35402 | .93524 | .37029 | .92892 | .38644 | .92231 | .40248 | .91543 | .41840 | .90826 | 16 |
| 45 | .35429 | .93514 | .37056 | .92881 | .38671 | .92220 | .40275 | .91531 | .41866 | .90814 | 15 |
| 46 | .35456 | .93503 | .37083 | .92870 | .38698 | .92209 | .40301 | .91519 | .41892 | .90802 | 14 |
| 47 | .35484 | .93493 | .37110 | .92859 | .38725 | .92198 | .40328 | .91508 | .41919 | .90790 | 13 |
| 48 | .35511 | .93483 | .37137 | .92849 | .38752 | .92186 | .40355 | .91496 | .41945 | .90778 | 12 |
| 49 | .35538 | .93472 | .37164 | .92838 | .38778 | .92175 | .40381 | .91484 | .41972 | .90766 | 11 |
| 50 | .35565 | .93462 | .37191 | .92827 | .38805 | .92164 | .40408 | .91472 | .41998 | .90753 | 10 |
| 51 | .35592 | .93452 | .37218 | .92816 | .38832 | .92152 | .40434 | .91461 | .42024 | .90741 | 9 |
| 52 | .35619 | .93441 | .37245 | .92805 | .38859 | .92141 | .40461 | .91449 | .42051 | .90729 | 8 |
| 53 | .35647 | .93431 | .37272 | .92794 | .38886 | .92130 | .40488 | .91437 | .42077 | .90717 | 7 |
| 54 | .35674 | .93420 | .37299 | .92784 | .38912 | .92119 | .40514 | .91425 | .42104 | .90704 | 6 |
| 55 | .35701 | .93410 | .37326 | .92773 | .38939 | .92107 | .40541 | .91414 | .42130 | .90692 | 5 |
| 56 | .35728 | .93400 | .37353 | .92762 | .38966 | .92096 | .40567 | .91402 | .42156 | .90680 | 4 |
| 57 | .35755 | .93389 | .37380 | .92751 | .38993 | .92085 | .40594 | .91390 | .42183 | .90668 | 3 |
| 58 | .35782 | .93379 | .37407 | .92740 | .39020 | .92073 | .40621 | .91378 | .42209 | .90655 | 2 |
| 59 | .35810 | .93368 | .37434 | .92729 | .39046 | .92062 | .40647 | .91366 | .42235 | .90643 | 1 |
| 60 | .35837 | .93358 | .37461 | .92718 | .39073 | .92050 | .40674 | .91355 | .42262 | .90631 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 69° | | 68° | | 67° | | 66° | | 65° | | |

| ′ | 25° | | 26° | | 27° | | 28° | | 29° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .42262 | .90631 | .43837 | .89879 | .45399 | .89101 | .46947 | .88295 | .48481 | .87462 | 60 |
| 1 | .42288 | .90618 | .43863 | .89867 | .45425 | .89087 | .46973 | .88281 | .48506 | .87448 | 59 |
| 2 | .42315 | .90606 | .43889 | .89854 | .45451 | .89074 | .46999 | .88267 | .48532 | .87434 | 58 |
| 3 | .42341 | .90594 | .43916 | .89841 | .45477 | .89061 | .47024 | .88254 | .48557 | .87420 | 57 |
| 4 | .42367 | .90582 | .43942 | .89828 | .45503 | .89048 | .47050 | .88240 | .48583 | .87406 | 56 |
| 5 | .42394 | .90569 | .43968 | .89816 | .45529 | .89035 | .47076 | .88226 | .48608 | .87391 | 55 |
| 6 | .42420 | .90557 | .43994 | .89803 | .45554 | .89021 | .47101 | .88213 | .48634 | .87377 | 54 |
| 7 | .42446 | .90545 | .44020 | .89790 | .45580 | .89008 | .47127 | .88199 | .48659 | .87363 | 53 |
| 8 | .42473 | .90532 | .44046 | .89777 | .45606 | .88995 | .47153 | .88185 | .48684 | .87349 | 52 |
| 9 | .42499 | .90520 | .44072 | .89764 | .45632 | .88981 | .47178 | .88172 | .48710 | .87335 | 51 |
| 10 | .42525 | .90507 | .44098 | .89752 | .45658 | .88968 | .47204 | .88158 | .48735 | .87321 | 50 |
| 11 | .42552 | .90495 | .44124 | .89739 | .45684 | .88955 | .47229 | .88144 | .48761 | .87306 | 49 |
| 12 | .42578 | .90483 | .44151 | .89726 | .45710 | .88942 | .47255 | .88130 | .48786 | .87292 | 48 |
| 13 | .42604 | .90470 | .44177 | .89713 | .45736 | .88928 | .47281 | .88117 | .48811 | .87278 | 47 |
| 14 | .42631 | .90458 | .44203 | .89700 | .45762 | .88915 | .47306 | .88103 | .48837 | .87264 | 46 |
| 15 | .42657 | .90446 | .44229 | .89687 | .45787 | .88902 | .47332 | .88089 | .48862 | .87250 | 45 |
| 16 | .42683 | .90433 | .44255 | .89674 | .45813 | .88888 | .47358 | .88075 | .48888 | .87235 | 44 |
| 17 | .42709 | .90421 | .44281 | .89662 | .45839 | .88875 | .47383 | .88062 | .48913 | .87221 | 43 |
| 18 | .42736 | .90408 | .44307 | .89649 | .45865 | .88862 | .47409 | .88048 | .48938 | .87207 | 42 |
| 19 | .42762 | .90396 | .44333 | .89636 | .45891 | .88848 | .47434 | .88034 | .48964 | .87193 | 41 |
| 20 | .42788 | .90383 | .44359 | .89623 | .45917 | .88835 | .47460 | .88020 | .48989 | .87178 | 40 |
| 21 | .42815 | .90371 | .44385 | .89610 | .45942 | .88822 | .47486 | .88006 | .49014 | .87164 | 39 |
| 22 | .42841 | .90358 | .44411 | .89597 | .45968 | .88808 | .47511 | .87993 | .49040 | .87150 | 38 |
| 23 | .42867 | .90346 | .44437 | .89584 | .45994 | .88795 | .47537 | .87979 | .49065 | .87136 | 37 |
| 24 | .42894 | .90334 | .44464 | .89571 | .46020 | .88782 | .47562 | .87965 | .49090 | .87121 | 36 |
| 25 | .42920 | .90321 | .44490 | .89558 | .46046 | .88768 | .47588 | .87951 | .49116 | .87107 | 35 |
| 26 | .42946 | .90309 | .44516 | .89545 | .46072 | .88755 | .47614 | .87937 | .49141 | .87093 | 34 |
| 27 | .42972 | .90296 | .44542 | .89532 | .46097 | .88741 | .47639 | .87923 | .49166 | .87079 | 33 |
| 28 | .42999 | .90284 | .44568 | .89519 | .46123 | .88728 | .47665 | .87909 | .49192 | .87064 | 32 |
| 29 | .43025 | .90271 | .44594 | .89506 | .46149 | .88715 | .47690 | .87896 | .49217 | .87050 | 31 |
| 30 | .43051 | .90259 | .44620 | .89493 | .46175 | .88701 | .47716 | .87882 | .49242 | .87036 | 30 |
| 31 | .43077 | .90246 | .44646 | .89480 | .46201 | .88688 | .47741 | .87868 | .49268 | .87021 | 29 |
| 32 | .43104 | .90233 | .44672 | .89467 | .46226 | .88674 | .47767 | .87854 | .49293 | .87007 | 28 |
| 33 | .43130 | .90221 | .44698 | .89454 | .46252 | .88661 | .47793 | .87840 | .49318 | .86993 | 27 |
| 34 | .43156 | .90208 | .44724 | .89441 | .46278 | .88647 | .47818 | .87826 | .49344 | .86978 | 26 |
| 35 | .43182 | .90196 | .44750 | .89428 | .46304 | .88634 | .47844 | .87812 | .49369 | .86964 | 25 |
| 36 | .43209 | .90183 | .44776 | .89415 | .46330 | .88620 | .47869 | .87798 | .49394 | .86949 | 24 |
| 37 | .43235 | .90171 | .44802 | .89402 | .46355 | .88607 | .47895 | .87784 | .49419 | .86935 | 23 |
| 38 | .43261 | .90158 | .44828 | .89389 | .46381 | .88593 | .47920 | .87770 | .49445 | .86921 | 22 |
| 39 | .43287 | .90146 | .44854 | .89376 | .46407 | .88580 | .47946 | .87756 | .49470 | .86906 | 21 |
| 40 | .43313 | .90133 | .44880 | .89363 | .46433 | .88566 | .47971 | .87743 | .49495 | .86892 | 20 |
| 41 | .43340 | .90120 | .44906 | .89350 | .46458 | .88553 | .47997 | .87729 | .49521 | .86878 | 19 |
| 42 | .43366 | .90108 | .44932 | .89337 | .46484 | .88539 | .48022 | .87715 | .49546 | .86863 | 18 |
| 43 | .43392 | .90095 | .44958 | .89324 | .46510 | .88526 | .48048 | .87701 | .49571 | .86849 | 17 |
| 44 | .43418 | .90082 | .44984 | .89311 | .46536 | .88512 | .48073 | .87687 | .49596 | .86834 | 16 |
| 45 | .43445 | .90070 | .45010 | .89298 | .46561 | .88499 | .48099 | .87673 | .49622 | .86820 | 15 |
| 46 | .43471 | .90057 | .45036 | .89285 | .46587 | .88485 | .48124 | .87659 | .49647 | .86805 | 14 |
| 47 | .43497 | .90045 | .45062 | .89272 | .46613 | .88472 | .48150 | .87645 | .49672 | .86791 | 13 |
| 48 | .43523 | .90032 | .45088 | .89259 | .46639 | .88458 | .48175 | .87631 | .49697 | .86777 | 12 |
| 49 | .43549 | .90019 | .45114 | .89245 | .46664 | .88445 | .48201 | .87617 | .49723 | .86762 | 11 |
| 50 | .43575 | .90007 | .45140 | .89232 | .46690 | .88431 | .48226 | .87603 | .49748 | .86748 | 10 |
| 51 | .43602 | .89994 | .45166 | .89219 | .46716 | .88417 | .48252 | .87589 | .49773 | .86733 | 9 |
| 52 | .43628 | .89981 | .45192 | .89206 | .46742 | .88404 | .48277 | .87575 | .49798 | .86719 | 8 |
| 53 | .43654 | .89968 | .45218 | .89193 | .46767 | .88390 | .48303 | .87561 | .49824 | .86704 | 7 |
| 54 | .43680 | .89956 | .45243 | .89180 | .46793 | .88377 | .48328 | .87546 | .49849 | .86690 | 6 |
| 55 | .43706 | .89943 | .45269 | .89167 | .46819 | .88363 | .48354 | .87532 | .49874 | .86675 | 5 |
| 56 | .43733 | .89930 | .45295 | .89153 | .46844 | .88349 | .48379 | .87518 | .49899 | .86661 | 4 |
| 57 | .43759 | .89918 | .45321 | .89140 | .46870 | .88336 | .48405 | .87504 | .49924 | .86646 | 3 |
| 58 | .43785 | .89905 | .45347 | .89127 | .46896 | .88322 | .48430 | .87490 | .49950 | .86632 | 2 |
| 59 | .43811 | .89892 | .45373 | .89114 | .46921 | .88308 | .48456 | .87476 | .49975 | .86617 | 1 |
| 60 | .43837 | .89879 | .45399 | .89101 | .46947 | .88295 | .48481 | .87462 | .50000 | .86603 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 64° | | 63° | | 62° | | 61° | | 60° | | |

| ′ | 30° |  | 31° |  | 32° |  | 33° |  | 34° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin |  |
| 0 | .50000 | .86603 | .51504 | .85717 | .52992 | .84805 | .54464 | .83867 | .55919 | .82904 | 60 |
| 1 | .50025 | .86588 | .51529 | .85702 | .53017 | .84789 | .54488 | .83851 | .55943 | .82887 | 59 |
| 2 | .50050 | .86573 | .51554 | .85687 | .53041 | .84774 | .54513 | .83835 | .55968 | .82871 | 58 |
| 3 | .50076 | .86559 | .51579 | .85672 | .53066 | .84759 | .54537 | .83819 | .55992 | .82855 | 57 |
| 4 | .50101 | .86544 | .51604 | .85657 | .53091 | .84743 | .54561 | .83804 | .56016 | .82839 | 56 |
| 5 | .50126 | .86530 | .51628 | .85642 | .53115 | .84728 | .54586 | .83788 | .56040 | .82822 | 55 |
| 6 | .50151 | .86515 | .51653 | .85627 | .53140 | .84712 | .54610 | .83772 | .56064 | .82806 | 54 |
| 7 | .50176 | .86501 | .51678 | .85612 | .53164 | .84697 | .54635 | .83756 | .56088 | .82790 | 53 |
| 8 | .50201 | .86486 | .51703 | .85597 | .53189 | .84681 | .54659 | .83740 | .56112 | .82773 | 52 |
| 9 | .50227 | .86471 | .51728 | .85582 | .53214 | .84666 | .54683 | .83724 | .56136 | .82757 | 51 |
| 10 | .50252 | .86457 | .51753 | .85567 | .53238 | .84650 | .54708 | .83708 | .56160 | .82741 | 50 |
| 11 | .50277 | .86442 | .51778 | .85551 | .53263 | .84635 | .54732 | .83692 | .56184 | .82724 | 49 |
| 12 | .50302 | .86427 | .51803 | .85536 | .53288 | .84619 | .54756 | .83676 | .56208 | .82708 | 48 |
| 13 | .50327 | .86413 | .51828 | .85521 | .53312 | .84604 | .54781 | .83660 | .56232 | .82692 | 47 |
| 14 | .50352 | .86398 | .51852 | .85506 | .53337 | .84588 | .54805 | .83645 | .56256 | .82675 | 46 |
| 15 | .50377 | .86384 | .51877 | .85491 | .53361 | .84573 | .54829 | .83629 | .56280 | .82659 | 45 |
| 16 | .50403 | .86369 | .51902 | .85476 | .53386 | .84557 | .54854 | .83613 | .56305 | .82643 | 44 |
| 17 | .50428 | .86354 | .51927 | .85461 | .53411 | .84542 | .54878 | .83597 | .56329 | .82626 | 43 |
| 18 | .50453 | .86340 | .51952 | .85446 | .53435 | .84526 | .54902 | .83581 | .56353 | .82610 | 42 |
| 19 | .50478 | .86325 | .51977 | .85431 | .53460 | .84511 | .54927 | .83565 | .56377 | .82593 | 41 |
| 20 | .50503 | .86310 | .52002 | .85416 | .53484 | .84495 | .54951 | .83549 | .56401 | .82577 | 40 |
| 21 | .50528 | .86295 | .52026 | .85401 | .53509 | .84480 | .54975 | .83533 | .56425 | .82561 | 39 |
| 22 | .50553 | .86281 | .52051 | .85385 | .53534 | .84464 | .54999 | .83517 | .56449 | .82544 | 38 |
| 23 | .50578 | .86266 | .52076 | .85370 | .53558 | .84448 | .55024 | .83501 | .56473 | .82528 | 37 |
| 24 | .50603 | .86251 | .52101 | .85355 | .53583 | .84433 | .55048 | .83485 | .56497 | .82511 | 36 |
| 25 | .50628 | .86237 | .52126 | .85340 | .53607 | .84417 | .55072 | .83469 | .56521 | .82495 | 35 |
| 26 | .50654 | .86222 | .52151 | .85325 | .53632 | .84402 | .55097 | .83453 | .56545 | .82478 | 34 |
| 27 | .50679 | .86207 | .52175 | .85310 | .53656 | .84386 | .55121 | .83437 | .56569 | .82462 | 33 |
| 28 | .50704 | .86192 | .52200 | .85294 | .53681 | .84370 | .55145 | .83421 | .56593 | .82446 | 32 |
| 29 | .50729 | .86178 | .52225 | .85279 | .53705 | .84355 | .55169 | .83405 | .56617 | .82429 | 31 |
| 30 | .50754 | .86163 | .52250 | .85264 | .53730 | .84339 | .55194 | .83389 | .56641 | .82413 | 30 |
| 31 | .50779 | .86148 | .52275 | .85249 | .53754 | .84324 | .55218 | .83373 | .56665 | .82396 | 29 |
| 32 | .50804 | .86133 | .52299 | .85234 | .53779 | .84308 | .55242 | .83356 | .56689 | .82380 | 28 |
| 33 | .50829 | .86119 | .52324 | .85218 | .53804 | .84292 | .55266 | .83340 | .56713 | .82363 | 27 |
| 34 | .50854 | .86104 | .52349 | .85203 | .53828 | .84277 | .55291 | .83324 | .56736 | .82347 | 26 |
| 35 | .50879 | .86089 | .52374 | .85188 | .53853 | .84261 | .55315 | .83308 | .56760 | .82330 | 25 |
| 36 | .50904 | .86074 | .52399 | .85173 | .53877 | .84245 | .55339 | .83292 | .56784 | .82314 | 24 |
| 37 | .50929 | .86059 | .52423 | .85157 | .53902 | .84230 | .55363 | .83276 | .56808 | .82297 | 23 |
| 38 | .50954 | .86045 | .52448 | .85142 | .53926 | .84214 | .55388 | .83260 | .56832 | .82281 | 22 |
| 39 | .50979 | .86030 | .52473 | .85127 | .53951 | .84198 | .55412 | .83244 | .56856 | .82264 | 21 |
| 40 | .51004 | 86015 | .52498 | .85112 | .53975 | .84182 | .55436 | .83228 | .56880 | .82248 | 20 |
| 41 | .51029 | .86000 | .52522 | .85096 | .54000 | .84167 | .55460 | .83212 | .56904 | .82231 | 19 |
| 42 | .51054 | .85985 | .52547 | .85081 | .54024 | .84151 | .55484 | .83195 | .56928 | .82214 | 18 |
| 43 | .51079 | .85970 | .52572 | .85066 | .54049 | .84135 | .55509 | .83179 | .56952 | .82198 | 17 |
| 44 | .51104 | .85956 | .52597 | .85051 | .54073 | .84120 | .55533 | .83163 | .56976 | .82181 | 16 |
| 45 | .51129 | .85941 | .52621 | .85035 | .54097 | .84104 | .55557 | .83147 | .57000 | .82165 | 15 |
| 46 | .51154 | .85926 | .52646 | .85020 | .54122 | .84088 | .55581 | .83131 | .57024 | .82148 | 14 |
| 47 | .51179 | .85911 | .52671 | .85005 | .54146 | .84072 | .55605 | .83115 | .57047 | .82132 | 13 |
| 48 | .51204 | .85896 | .52696 | .84989 | .54171 | .84057 | .55630 | .83098 | .57071 | .82115 | 12 |
| 49 | .51229 | .85881 | .52720 | .84974 | .54195 | .84041 | .55654 | .83082 | .57095 | .82098 | 11 |
| 50 | .51254 | .85866 | .52745 | .84959 | .54220 | .84025 | .55678 | .83066 | .57119 | .82082 | 10 |
| 51 | .51279 | .85851 | .52770 | .84943 | .54244 | .84009 | .55702 | .83050 | .57143 | .82065 | 9 |
| 52 | .51304 | .85836 | .52794 | .84928 | .54269 | .83994 | .55726 | .83034 | .57167 | .82048 | 8 |
| 53 | .51329 | .85821 | .52819 | .84913 | .54293 | .83978 | .55750 | .83017 | .57191 | .82032 | 7 |
| 54 | .51354 | .85806 | .52844 | .84897 | .54317 | .83962 | .55775 | .83001 | .57215 | .82015 | 6 |
| 55 | .51379 | .85792 | .52869 | .84882 | .54342 | .83946 | .55799 | .82985 | .57238 | .81999 | 5 |
| 56 | .51404 | .85777 | .52893 | .84866 | .54366 | .83930 | .55823 | .82969 | .57262 | .81982 | 4 |
| 57 | .51429 | .85762 | .52918 | .84851 | .54391 | .83915 | .55847 | .82953 | .57286 | .81965 | 3 |
| 58 | .51454 | .85747 | .52943 | .84836 | .54415 | .83899 | .55871 | .82936 | .57310 | .81949 | 2 |
| 59 | .51479 | .85732 | .52967 | .84820 | .54440 | .83883 | .55895 | .82920 | .57334 | .81932 | 1 |
| 60 | .51504 | .85717 | .52992 | .84805 | .54464 | .83867 | .55919 | .82904 | .57358 | .81915 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
|  | 59° |  | 58° |  | 57° |  | 56° |  | 55° |  |  |

| ′ | 35° | | 36° | | 37° | | 38° | | 39° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .57358 | .81915 | .58779 | .80902 | .60182 | .79864 | .61566 | .78801 | .62932 | .77715 | 60 |
| 1 | .57381 | .81899 | .58802 | .80885 | .60205 | .79846 | .61589 | .78783 | .62955 | .77696 | 59 |
| 2 | .57405 | .81882 | .58826 | .80867 | .60228 | .79829 | .61612 | .78765 | .62977 | .77678 | 58 |
| 3 | .57429 | .81865 | .58849 | .80850 | .60251 | .79811 | .61635 | .78747 | .63000 | .77660 | 57 |
| 4 | .57453 | .81848 | .58873 | .80833 | .60274 | .79793 | .61658 | .78729 | .63022 | .77641 | 56 |
| 5 | .57477 | .81832 | .58896 | .80816 | .60298 | .79776 | .61681 | .78711 | .63045 | .77623 | 55 |
| 6 | .57501 | .81815 | .58920 | .80799 | .60321 | .79758 | .61704 | .78694 | .63068 | .77605 | 54 |
| 7 | .57524 | .81798 | .58943 | .80782 | .60344 | .79741 | .61726 | .78676 | .63090 | .77586 | 53 |
| 8 | .57548 | .81782 | .58967 | .80765 | .60367 | .79723 | .61749 | .78658 | .63113 | .77568 | 52 |
| 9 | .57572 | .81765 | .58990 | .80748 | .60390 | .79706 | .61772 | .78640 | .63135 | .77550 | 51 |
| 10 | .57596 | .81748 | .59014 | .80730 | .60414 | .79688 | .61795 | .78622 | .63158 | .77531 | 50 |
| 11 | .57619 | .81731 | .59037 | .80713 | .60437 | .79671 | .61818 | .78604 | .63180 | .77513 | 49 |
| 12 | .57643 | .81714 | .59061 | .80696 | .60460 | .79653 | .61841 | .78586 | .63203 | .77494 | 48 |
| 13 | .57667 | .81698 | .59084 | .80679 | .60483 | .79635 | .61864 | .78568 | .63225 | .77476 | 47 |
| 14 | .57691 | .81681 | .59108 | .80662 | .60506 | .79618 | .61887 | .78550 | .63248 | .77458 | 46 |
| 15 | .57715 | .81664 | .59131 | .80644 | .60529 | .79600 | .61909 | .78532 | .63271 | .77439 | 45 |
| 16 | .57738 | .81647 | .59154 | .80627 | .60553 | .79583 | .61932 | .78514 | .63293 | .77421 | 44 |
| 17 | .57762 | .81631 | .59178 | .80610 | .60576 | .79565 | .61955 | .78496 | .63316 | .77402 | 43 |
| 18 | .57786 | .81614 | .59201 | .80593 | .60599 | .79547 | .61978 | .78478 | .63338 | .77384 | 42 |
| 19 | .57810 | .81597 | .59225 | .80576 | .60622 | .79530 | .62001 | .78460 | .63361 | .77366 | 41 |
| 20 | .57833 | .81580 | .59248 | .80558 | .60645 | .79512 | .62024 | .78442 | .63383 | .77347 | 40 |
| 21 | .57857 | .81563 | .59272 | .80541 | .60668 | .79494 | .62046 | .78424 | .63406 | .77329 | 39 |
| 22 | .57881 | .81546 | .59295 | .80524 | .60691 | .79477 | .62069 | .78405 | .63428 | .77310 | 38 |
| 23 | .57904 | .81530 | .59318 | .80507 | .60714 | .79459 | .62092 | .78387 | .63451 | .77292 | 37 |
| 24 | .57928 | .81513 | .59342 | .80489 | .60738 | .79441 | .62115 | .78369 | .63473 | .77273 | 36 |
| 25 | .57952 | .81496 | .59365 | .80472 | .60761 | .79424 | .62138 | .78351 | .63496 | .77255 | 35 |
| 26 | .57976 | .81479 | .59389 | .80455 | .60784 | .79406 | .62160 | .78333 | .63518 | .77236 | 34 |
| 27 | .57999 | .81462 | .59412 | .80438 | .60807 | .79388 | .62183 | .78315 | .63540 | .77218 | 33 |
| 28 | .58023 | .81445 | .59436 | .80420 | .60830 | .79371 | .62206 | .78297 | .63563 | .77199 | 32 |
| 29 | .58047 | .81428 | .59459 | .80403 | 60853 | .79353 | .62229 | .78279 | .63585 | .77181 | 31 |
| 30 | .58070 | .81412 | .59482 | .80386 | .60876 | .79335 | .62251 | .78261 | .63608 | .77162 | 30 |
| 31 | .58094 | .81395 | .59506 | .80368 | .60899 | .79318 | .62274 | .78243 | .63630 | .77144 | 29 |
| 32 | .58118 | .81378 | .59529 | .80351 | .60922 | .79300 | .62297 | .78225 | .63653 | .77125 | 28 |
| 33 | .58141 | .81361 | .59552 | .80334 | .60945 | .79282 | .62320 | .78206 | .63675 | .77107 | 27 |
| 34 | .58165 | .81344 | .59576 | .80316 | .60968 | .79264 | .62342 | .78188 | .63698 | .77088 | 26 |
| 35 | .58189 | .81327 | .59599 | .80299 | .60991 | .79247 | .62365 | .78170 | .63720 | .77070 | 25 |
| 36 | .58212 | .81310 | .59622 | .80282 | .61015 | .79229 | .62388 | .78152 | .63742 | .77051 | 24 |
| 37 | .58236 | .81293 | .59646 | .80264 | .61038 | .79211 | .62411 | .78134 | .63765 | .77033 | 23 |
| 38 | .58260 | .81276 | .59669 | .80247 | .61061 | .79193 | .62433 | .78116 | .63787 | .77014 | 22 |
| 39 | .58283 | .81259 | .59693 | .80230 | .61084 | .79176 | .62456 | .78098 | .63810 | .76996 | 21 |
| 40 | .58307 | .81242 | .59716 | .80212 | .61107 | .79158 | .62479 | .78079 | .63832 | .76977 | 20 |
| 41 | .58330 | .81225 | .59739 | .80195 | .61130 | .79140 | .62502 | .78061 | .63854 | .76959 | 19 |
| 42 | .58354 | .81208 | .59763 | .80178 | .61153 | .79122 | .62524 | .78043 | .63877 | .76940 | 18 |
| 43 | .58378 | .81191 | .59786 | .80160 | .61176 | .79105 | .62547 | .78025 | .63899 | .76921 | 17 |
| 44 | .58401 | .81174 | .59809 | .80143 | .61199 | .79087 | .62570 | .78007 | .63922 | .76903 | 16 |
| 45 | .58425 | .81157 | .59832 | .80125 | .61222 | .79069 | .62592 | .77988 | .63944 | .76884 | 15 |
| 46 | .58449 | .81140 | .59856 | .80108 | .61245 | .79051 | .62615 | .77970 | .63966 | .76866 | 14 |
| 47 | .58472 | .81123 | .59879 | .80091 | .61268 | .79033 | .62638 | .77952 | .63989 | .76847 | 13 |
| 48 | .58496 | .81106 | .59902 | .80073 | .61291 | .79016 | .62660 | .77934 | .64011 | .76828 | 12 |
| 49 | .58519 | .81089 | .59926 | .80056 | .61314 | .78998 | .62683 | .77916 | .64033 | .76810 | 11 |
| 50 | .58543 | .81072 | .59949 | .80038 | .61337 | .78980 | .62706 | .77897 | .64056 | .76791 | 10 |
| 51 | .58567 | .81055 | .59972 | .80021 | .61360 | .78962 | .62728 | .77879 | .64078 | .76772 | 9 |
| 52 | .58590 | .81038 | .59995 | .80003 | .61383 | .78944 | .62751 | .77861 | .64100 | .76754 | 8 |
| 53 | .58614 | .81021 | .60019 | .79986 | .61406 | .78926 | .62774 | .77843 | .64123 | .76735 | 7 |
| 54 | .58637 | .81004 | .60042 | .79968 | .61429 | .78908 | .62796 | .77824 | .64145 | .76717 | 6 |
| 55 | .58661 | .80987 | .60065 | .79951 | .61451 | .78891 | .62819 | .77806 | .64167 | .76698 | 5 |
| 56 | .58684 | .80970 | .60089 | .79934 | .61474 | .78873 | .62842 | .77788 | .64190 | .76679 | 4 |
| 57 | .58708 | .80953 | .60112 | .79916 | .61497 | .78855 | .62864 | .77769 | .64212 | .76661 | 3 |
| 58 | .58731 | .80936 | .60135 | .79899 | .61520 | .78837 | .62887 | .77751 | .64234 | .76642 | 2 |
| 59 | .58755 | .80919 | .60158 | .79881 | .61543 | .78819 | .62909 | .77733 | .64256 | .76623 | 1 |
| 60 | .58779 | .80902 | .60182 | .79864 | .61566 | .78801 | .62932 | .77715 | .64279 | .76604 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 54° | | 53° | | 52° | | 51° | | 50° | | |

| ′ | 40° | | 41° | | 42° | | 43° | | 44° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | |
| 0 | .64279 | .76604 | .65606 | .75471 | .66913 | .74314 | .68200 | .73135 | .69466 | .71934 | 60 |
| 1 | .64301 | .76586 | .65628 | .75452 | .66935 | .74295 | .68221 | .73116 | .69487 | .71914 | 59 |
| 2 | .64323 | .76567 | .65650 | .75433 | .66956 | .74276 | .68242 | .73096 | .69508 | .71894 | 58 |
| 3 | .64346 | .76548 | .65672 | .75414 | .66978 | .74256 | .68264 | .73076 | .69529 | .71873 | 57 |
| 4 | .64368 | .76530 | .65694 | .75395 | .66999 | .74237 | .68285 | .73056 | .69549 | .71853 | 56 |
| 5 | .64390 | .76511 | .65716 | .75375 | .67021 | .74217 | .68306 | .73036 | .69570 | .71833 | 55 |
| 6 | .64412 | .76492 | .65738 | .75356 | .67043 | .74198 | .68327 | .73016 | .69591 | .71813 | 54 |
| 7 | .64435 | .76473 | .65759 | .75337 | .67064 | .74178 | .68349 | .72996 | .69612 | .71792 | 53 |
| 8 | .64457 | .76455 | .65781 | .75318 | .67086 | .74159 | .68370 | .72976 | .69633 | .71772 | 52 |
| 9 | .64479 | .76436 | .65803 | .75299 | .67107 | .74139 | .68391 | .72957 | .69654 | .71752 | 51 |
| 10 | .64501 | .76417 | .65825 | .75280 | .67129 | .74120 | .68412 | .72937 | .69675 | .71732 | 50 |
| 11 | .64524 | .76398 | .65847 | .75261 | .67151 | .74100 | .68434 | .72917 | .69696 | .71711 | 49 |
| 12 | .64546 | .76380 | .65869 | .75241 | .67172 | .74080 | .68455 | .72897 | .69717 | .71691 | 48 |
| 13 | .64568 | .76361 | .65891 | .75222 | .67194 | .74061 | .68476 | .72877 | .69737 | .71671 | 47 |
| 14 | .64590 | .76342 | .65913 | .75203 | .67215 | .74041 | .68497 | .72857 | .69758 | .71650 | 46 |
| 15 | .64612 | .76323 | .65935 | .75184 | .67237 | .74022 | .68518 | .72837 | .69779 | .71630 | 45 |
| 16 | .64635 | .76304 | .65956 | .75165 | .67258 | .74002 | .68539 | .72817 | .69800 | .71610 | 44 |
| 17 | .64657 | .76286 | .65978 | .75146 | .67280 | .73983 | .68561 | .72797 | .69821 | .71590 | 43 |
| 18 | .64679 | .76267 | .66000 | .75126 | .67301 | .73963 | .68582 | .72777 | .69842 | .71569 | 42 |
| 19 | .64701 | .76248 | .66022 | .75107 | .67323 | .73944 | .68603 | .72757 | .69862 | .71549 | 41 |
| 20 | .64723 | .76229 | .66044 | .75088 | .67344 | .73924 | .68624 | .72737 | .69883 | .71529 | 40 |
| 21 | .64746 | .76210 | .66066 | .75069 | .67366 | .73904 | .68645 | .72717 | .69904 | .71508 | 39 |
| 22 | .64768 | .76192 | .66088 | .75050 | .67387 | .73885 | .68666 | .72697 | .69925 | .71488 | 38 |
| 23 | .64790 | .76173 | .66109 | .75030 | .67409 | .73865 | .68688 | .72677 | .69946 | .71468 | 37 |
| 24 | .64812 | .76154 | .66131 | .75011 | .67430 | .73846 | .68709 | .72657 | .69966 | .71447 | 36 |
| 25 | .64834 | .76135 | .66153 | .74992 | .67452 | .73826 | .68730 | .72637 | .69987 | .71427 | 35 |
| 26 | .64856 | .76116 | .66175 | .74973 | .67473 | .73806 | .68751 | .72617 | .70008 | .71407 | 34 |
| 27 | .64878 | .76097 | .66197 | .74953 | .67495 | .73787 | .68772 | .72597 | .70029 | .71386 | 33 |
| 28 | .64901 | .76078 | .66218 | .74934 | .67516 | .73767 | .68793 | .72577 | .70049 | .71366 | 32 |
| 29 | .64923 | .76059 | .66240 | .74915 | .67538 | .73747 | .68814 | .72557 | .70070 | .71345 | 31 |
| 30 | .64945 | .76041 | .66262 | .74896 | .67559 | .73728 | .68835 | .72537 | .70091 | .71325 | 30 |
| 31 | .64967 | .76022 | .66284 | .74876 | .67580 | .73708 | .68857 | .72517 | .70112 | .71305 | 29 |
| 32 | .64989 | .76003 | .66306 | .74857 | .67602 | .73688 | .68878 | .72497 | 70132 | .71284 | 28 |
| 33 | .65011 | .75984 | .66327 | .74838 | .67623 | .73669 | .68899 | .72477 | .70153 | .71264 | 27 |
| 34 | .65033 | .75965 | .66349 | .74818 | .67645 | .73649 | .68920 | .72457 | .70174 | .71243 | 26 |
| 35 | .65055 | .75946 | .66371 | .74799 | .67666 | .73629 | .68941 | .72437 | .70195 | .71223 | 35 |
| 36 | .65077 | .75927 | .66393 | .74780 | .67688 | .73610 | .68962 | .72417 | .70215 | .71203 | 24 |
| 37 | .65100 | .75908 | .66414 | .74760 | .67709 | .73590 | .68983 | .72397 | .70236 | .71182 | 23 |
| 38 | .65122 | .75889 | .66436 | .74741 | .67730 | 73570 | .69004 | .72377 | .70257 | .71162 | 22 |
| 39 | .65144 | .75870 | .66458 | .74722 | .67752 | .73551 | .69025 | .72357 | .70277 | .71141 | 21 |
| 40 | .65166 | .75851 | .66480 | .74703 | .67773 | .73531 | .69046 | .72337 | .70298 | .71121 | 20 |
| 41 | .65188 | .75832 | .66501 | .74683 | .67795 | .73511 | .69067 | .72317 | .70319 | .71100 | 19 |
| 42 | .65210 | .75813 | .66523 | .74664 | .67816 | .73491 | .69088 | .72297 | .70339 | .71080 | 18 |
| 43 | .65232 | .75794 | .66545 | .74644 | .67837 | .73472 | .69109 | .72277 | .70360 | .71059 | 17 |
| 44 | .65254 | .75775 | .66566 | .74625 | .67859 | .73452 | .69130 | .72257 | .70381 | .71039 | 16 |
| 45 | .65276 | .75756 | .66588 | .74606 | .67880 | .73432 | .69151 | .72236 | .70401 | .71019 | 15 |
| 46 | .65298 | .75738 | .66610 | .74586 | .67901 | .73413 | .69172 | .72216 | .70422 | .70998 | 14 |
| 47 | .65320 | .75719 | .66632 | .74567 | .67923 | .73393 | .69193 | .72196 | .70443 | .70978 | 13 |
| 48 | .65342 | .75700 | .66653 | .74548 | .67944 | .73373 | .69214 | .72176 | .70463 | .70957 | 12 |
| 49 | .65364 | .75680 | .66675 | .74528 | .67965 | .73353 | .69235 | .72156 | .70484 | .70937 | 11 |
| 50 | .65386 | .75661 | .66697 | .74509 | .67987 | .73333 | .69256 | .72136 | .70505 | .70916 | 10 |
| 51 | .65408 | .75642 | .66718 | .74489 | .68008 | .73314 | .69277 | .72116 | .70525 | .70896 | 9 |
| 52 | .65430 | .75623 | .66740 | .74470 | .68029 | .73294 | .69298 | .72095 | .70546 | .70875 | 8 |
| 53 | .65452 | .75604 | .66762 | .74451 | .68051 | .73274 | .69319 | .72075 | .70567 | .70855 | 7 |
| 54 | .65474 | .75585 | .66783 | .74431 | .68072 | .73254 | .69340 | .72055 | .70587 | .70834 | 6 |
| 55 | .65496 | .75566 | .66805 | .74412 | .68093 | .73234 | .69361 | .72035 | .70608 | .70813 | 5 |
| 56 | .65518 | .75547 | .66827 | .74392 | .68115 | .73215 | .69382 | .72015 | .70628 | .70793 | 4 |
| 57 | .65540 | .75528 | .66848 | .74373 | .68136 | .73195 | .69403 | .71995 | .70649 | .70772 | 3 |
| 58 | .65562 | .75509 | .66870 | .74352 | .68157 | .73175 | .69424 | .71974 | .70670 | .70752 | 2 |
| 59 | .65584 | .75490 | .66891 | .74334 | .68179 | .73155 | .69445 | .71954 | .70690 | .70731 | 1 |
| 60 | .65606 | .75471 | .66913 | .74314 | .68200 | .73135 | .69466 | .71934 | .70711 | .70711 | 0 |
| ′ | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | Cosin | Sine | ′ |
| | 49° | | 48° | | 47° | | 46° | | 45° | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 0° | 1° | 2° | 3° | 4° | 5° | 6° | |
| 0 | 1.00000 | 1.00015 | 1.00061 | 1.00137 | 1.00244 | 1.00382 | 1.00551 | 60 |
| 1 | 00000 | 00016 | 00062 | 00139 | 00246 | 00385 | 00554 | 59 |
| 2 | 00000 | 00016 | 00063 | 00140 | 00248 | 00387 | 00557 | 58 |
| 3 | 00000 | 00017 | 00064 | 00142 | 00250 | 00390 | 00560 | 57 |
| 4 | 00000 | 00017 | 00065 | 00143 | 00252 | 00392 | 00563 | 56 |
| 5 | 00000 | 00018 | 00066 | 00145 | 00254 | 00395 | 00566 | 55 |
| 6 | 00000 | 00018 | 00067 | 00147 | 00257 | 00397 | 00569 | 54 |
| 7 | 00000 | 00019 | 00068 | 00148 | 00259 | 00400 | 00573 | 53 |
| 8 | 00000 | 00020 | 00069 | 00150 | 00261 | 00403 | 00576 | 52 |
| 9 | 00000 | 00020 | 00070 | 00151 | 00263 | 00405 | 00579 | 51 |
| 10 | 00000 | 00021 | 00072 | 00153 | 00265 | 00408 | 00582 | 50 |
| 11 | 1.00001 | 1.00021 | 1.00073 | 1.00155 | 1.00267 | 1.00411 | 1.00585 | 49 |
| 12 | 00001 | 00022 | 00074 | 00156 | 00269 | 00413 | 00588 | 48 |
| 13 | 00001 | 00023 | 00075 | 00158 | 00271 | 00416 | 00592 | 47 |
| 14 | 00001 | 00023 | 00076 | 00159 | 00274 | 00419 | 00595 | 46 |
| 15 | 00001 | 00024 | 00077 | 00161 | 00276 | 00421 | 00598 | 45 |
| 16 | 00001 | 00024 | 00078 | 00163 | 00278 | 00424 | 00601 | 44 |
| 17 | 00001 | 00025 | 00079 | 00164 | 00280 | 00427 | 00604 | 43 |
| 18 | 00001 | 00026 | 00081 | 00166 | 00282 | 00429 | 00608 | 42 |
| 19 | 00002 | 00026 | 00082 | 00168 | 00284 | 00432 | 00611 | 41 |
| 20 | 00002 | 00027 | 00083 | 00169 | 00287 | 00435 | 00614 | 40 |
| 21 | 1.00002 | 1.00028 | 1.00084 | 1.00171 | 1.00289 | 1.00438 | 1.00617 | 39 |
| 22 | 00002 | 00028 | 00085 | 00173 | 00291 | 00440 | 00621 | 38 |
| 23 | 00002 | 00029 | 00087 | 00175 | 00293 | 00443 | 00624 | 37 |
| 24 | 00002 | 00030 | 00088 | 00176 | 00296 | 00446 | 00627 | 36 |
| 25 | 00003 | 00031 | 00089 | 00178 | 00298 | 00449 | 00630 | 35 |
| 26 | 00003 | 00031 | 00090 | 00180 | 00300 | 00451 | 00634 | 34 |
| 27 | 00003 | 00032 | 00091 | 00182 | 00302 | 00454 | 00637 | 33 |
| 28 | 00003 | 00033 | 00093 | 00183 | 00305 | 00457 | 00640 | 32 |
| 29 | 00004 | 00034 | 00094 | 00185 | 00307 | 00460 | 00644 | 31 |
| 30 | 00004 | 00034 | 00095 | 00187 | 00309 | 00463 | 00647 | 30 |
| 31 | 1.00004 | 1.00035 | 1.00097 | 1.00189 | 1.00312 | 1.00465 | 1.00650 | 29 |
| 32 | 00004 | 00036 | 00098 | 00190 | 00314 | 00468 | 00654 | 28 |
| 33 | 00005 | 00037 | 00099 | 00192 | 00316 | 00471 | 00657 | 27 |
| 34 | 00005 | 00037 | 00100 | 00194 | 00318 | 00474 | 00660 | 26 |
| 35 | 00005 | 00038 | 00102 | 00196 | 00321 | 00477 | 00664 | 25 |
| 36 | 00005 | 00039 | 00103 | 00198 | 00323 | 00480 | 00667 | 24 |
| 37 | 00006 | 00040 | 00104 | 00200 | 00326 | 00482 | 00671 | 23 |
| 38 | 00006 | 00041 | 00106 | 00201 | 00328 | 00485 | 00674 | 22 |
| 39 | 00006 | 00041 | 00107 | 00203 | 00330 | 00488 | 00677 | 21 |
| 40 | 00007 | 00042 | 00108 | 00205 | 00333 | 00491 | 00681 | 20 |
| 41 | 1.00007 | 1.00043 | 1.00110 | 1.00207 | 1.00335 | 1.00494 | 1.00684 | 19 |
| 42 | 00007 | 00044 | 00111 | 00209 | 00337 | 00497 | 00688 | 18 |
| 43 | 00008 | 00045 | 00113 | 00211 | 00340 | 00500 | 00691 | 17 |
| 44 | 00008 | 00046 | 00114 | 00213 | 00342 | 00503 | 00695 | 16 |
| 45 | 00009 | 00047 | 00115 | 00215 | 00345 | 00506 | 00698 | 15 |
| 46 | 00009 | 00048 | 00117 | 00216 | 00347 | 00509 | 00701 | 14 |
| 47 | 00009 | 00048 | 00118 | 00218 | 00350 | 00512 | 00705 | 13 |
| 48 | 00010 | 00049 | 00120 | 00220 | 00352 | 00515 | 00708 | 12 |
| 49 | 00010 | 00050 | 00121 | 00222 | 00354 | 00518 | 00712 | 11 |
| 50 | 00011 | 00051 | 00122 | 00224 | 00357 | 00521 | 00715 | 10 |
| 51 | 1.00011 | 1.00052 | 1.00124 | 1.00226 | 1.00359 | 1.00524 | 1.00719 | 9 |
| 52 | 00011 | 00053 | 00125 | 00228 | 00362 | 00527 | 00722 | 8 |
| 53 | 00012 | 00054 | 00127 | 00230 | 00364 | 00530 | 00726 | 7 |
| 54 | 00012 | 00055 | 00128 | 00232 | 00367 | 00533 | 00730 | 6 |
| 55 | 00013 | 00056 | 00130 | 00234 | 00369 | 00536 | 00733 | 5 |
| 56 | 00013 | 00057 | 00131 | 00236 | 00372 | 00539 | 00737 | 4 |
| 57 | 00014 | 00058 | 00133 | 00238 | 00374 | 00542 | 00740 | 3 |
| 58 | 00014 | 00059 | 00134 | 00240 | 00377 | 00545 | 00744 | 2 |
| 59 | 00015 | 00060 | 00136 | 00242 | 00379 | 00548 | 00747 | 1 |
| 60 | 00015 | 00061 | 00137 | 00244 | 00382 | 00551 | 00751 | 0 |
| ′ | 89° | 88° | 87° | 86° | 85° | 84° | 83° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 7° | 8° | 9° | 10° | 11° | 12° | 13° | |
| 0 | 1.00751 | 1.00983 | 1.01247 | 1.01543 | 1.01872 | 1.02234 | 1.02630 | 60 |
| 1 | 00755 | 00987 | 01251 | 01548 | 01877 | 02240 | 02637 | 59 |
| 2 | 00758 | 00991 | 01256 | 01553 | 01883 | 02247 | 02644 | 58 |
| 3 | 00762 | 00995 | 01261 | 01558 | 01889 | 02253 | 02651 | 57 |
| 4 | 00765 | 00999 | 01265 | 01564 | 01895 | 02259 | 02658 | 56 |
| 5 | 00769 | 01004 | 01270 | 01569 | 01901 | 02266 | 02665 | 55 |
| 6 | 00773 | 01008 | 01275 | 01574 | 01906 | 02272 | 02672 | 54 |
| 7 | 00776 | 01012 | 01279 | 01579 | 01912 | 02279 | 02679 | 53 |
| 8 | 00780 | 01016 | 01284 | 01585 | 01918 | 02285 | 02686 | 52 |
| 9 | 00784 | 01020 | 01289 | 01590 | 01924 | 02291 | 02693 | 51 |
| 10 | 00787 | 01024 | 01294 | 01595 | 01930 | 02298 | 02700 | 50 |
| 11 | 1.00791 | 1.01029 | 1.01298 | 1.01601 | 1.01936 | 1.02304 | 1.02707 | 49 |
| 12 | 00795 | 01033 | 01303 | 01606 | 01941 | 02311 | 02714 | 48 |
| 13 | 00799 | 01037 | 01308 | 01611 | 01947 | 02317 | 02721 | 47 |
| 14 | 00802 | 01041 | 01313 | 01616 | 01953 | 02323 | 02728 | 46 |
| 15 | 00806 | 01046 | 01318 | 01622 | 01959 | 02330 | 02735 | 45 |
| 16 | 00810 | 01050 | 01322 | 01627 | 01965 | 02336 | 02742 | 44 |
| 17 | 00813 | 01054 | 01327 | 01633 | 01971 | 02343 | 02749 | 43 |
| 18 | 00817 | 01059 | 01332 | 01638 | 01977 | 02349 | 02756 | 42 |
| 19 | 00821 | 01063 | 01337 | 01643 | 01983 | 02356 | 02763 | 41 |
| 20 | 00825 | 01067 | 01342 | 01649 | 01989 | 02362 | 02770 | 40 |
| 21 | 1.00828 | 1.01071 | 1.01346 | 1.01654 | 1.01995 | 1.02369 | 1.02777 | 39 |
| 22 | 00832 | 01076 | 01351 | 01659 | 02001 | 02375 | 02784 | 38 |
| 23 | 00836 | 01080 | 01356 | 01665 | 02007 | 02382 | 02791 | 37 |
| 24 | 00840 | 01084 | 01361 | 01670 | 02013 | 02388 | 02799 | 36 |
| 25 | 00844 | 01089 | 01366 | 01676 | 02019 | 02395 | 02806 | 35 |
| 26 | 00848 | 01093 | 01371 | 01681 | 02025 | 02402 | 02813 | 34 |
| 27 | 00851 | 01097 | 01376 | 01687 | 02031 | 02408 | 02820 | 33 |
| 28 | 00855 | 01102 | 01381 | 01692 | 02037 | 02415 | 02827 | 32 |
| 29 | 00859 | 01106 | 01386 | 01698 | 02043 | 02421 | 02834 | 31 |
| 30 | 00863 | 01111 | 01391 | 01703 | 02049 | 02428 | 02842 | 30 |
| 31 | 1.00867 | 1.01115 | 1.01395 | 1.01709 | 1.02055 | 1.02435 | 1.02849 | 29 |
| 32 | 00871 | 01119 | 01400 | 01714 | 02061 | 02441 | 02856 | 28 |
| 33 | 00875 | 01124 | 01405 | 01720 | 02067 | 02448 | 02863 | 27 |
| 34 | 00878 | 01128 | 01410 | 01725 | 02073 | 02454 | 02870 | 26 |
| 35 | 00882 | 01133 | 01415 | 01731 | 02079 | 02461 | 02878 | 25 |
| 36 | 00886 | 01137 | 01420 | 01736 | 02085 | 02468 | 02885 | 24 |
| 37 | 00890 | 01142 | 01425 | 01742 | 02091 | 02474 | 02892 | 23 |
| 38 | 00894 | 01146 | 01430 | 01747 | 02097 | 02481 | 02899 | 22 |
| 39 | 00898 | 01151 | 01435 | 01753 | 02103 | 02488 | 02907 | 21 |
| 40 | 00902 | 01155 | 01440 | 01758 | 02110 | 02494 | 02914 | 20 |
| 41 | 1.00906 | 1.01160 | 1.01445 | 1.01764 | 1.02116 | 1.02501 | 1.02921 | 19 |
| 42 | 00910 | 01164 | 01450 | 01769 | 02122 | 02508 | 02928 | 18 |
| 43 | 00914 | 01169 | 01455 | 01775 | 02128 | 02515 | 02936 | 17 |
| 44 | 00918 | 01173 | 01461 | 01781 | 02134 | 02521 | 02943 | 16 |
| 45 | 00922 | 01178 | 01466 | 01786 | 02140 | 02528 | 02950 | 15 |
| 46 | 00926 | 01182 | 01471 | 01792 | 02146 | 02535 | 02958 | 14 |
| 47 | 00930 | 01187 | 01476 | 01798 | 02153 | 02542 | 02965 | 13 |
| 48 | 00934 | 01191 | 01481 | 01803 | 02159 | 02548 | 02972 | 12 |
| 49 | 00938 | 01196 | 01486 | 01809 | 02165 | 02555 | 02980 | 11 |
| 50 | 00942 | 01200 | 01491 | 01815 | 02171 | 02562 | 02987 | 10 |
| 51 | 1.00946 | 1.01205 | 1.01496 | 1.01820 | 1.02178 | 1.02569 | 1.02994 | 9 |
| 52 | 00950 | 01209 | 01501 | 01826 | 02184 | 02576 | 03002 | 8 |
| 53 | 00954 | 01214 | 01506 | 01832 | 02190 | 02582 | 03009 | 7 |
| 54 | 00958 | 01219 | 01512 | 01837 | 02196 | 02589 | 03017 | 6 |
| 55 | 00962 | 01223 | 01517 | 01843 | 02203 | 02596 | 03024 | 5 |
| 56 | 00966 | 01228 | 01522 | 01849 | 02209 | 02603 | 03032 | 4 |
| 57 | 00970 | 01233 | 01527 | 01854 | 02215 | 02610 | 03039 | 3 |
| 58 | 00975 | 01237 | 01532 | 01860 | 02221 | 02617 | 03046 | 2 |
| 59 | 00979 | 01242 | 01537 | 01866 | 02228 | 02624 | 03054 | 1 |
| 60 | 00983 | 01247 | 01543 | 01872 | 02234 | 02630 | 03061 | 0 |
| ′ | 82° | 81° | 80° | 79° | 78° | 77° | 76° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 14° | 15° | 16° | 17° | 18° | 19° | 20° | |
| 0 | 1.03061 | 1.03528 | 1.04030 | 1.04569 | 1.05146 | 1.05762 | 1.06418 | 60 |
| 1 | 03069 | 03536 | 04039 | 04578 | 05156 | 05773 | 06429 | 59 |
| 2 | 03076 | 03544 | 04047 | 04588 | 05166 | 05783 | 06440 | 58 |
| 3 | 03084 | 03552 | 04056 | 04597 | 05176 | 05794 | 06452 | 57 |
| 4 | 03091 | 03560 | 04065 | 04606 | 05186 | 05805 | 06463 | 56 |
| 5 | 03099 | 03568 | 04073 | 04616 | 05196 | 05815 | 06474 | 55 |
| 6 | 03106 | 03576 | 04082 | 04625 | 05206 | 05826 | 06486 | 54 |
| 7 | 03114 | 03584 | 04091 | 04635 | 05216 | 05836 | 06497 | 53 |
| 8 | 03121 | 03592 | 04100 | 04644 | 05226 | 05847 | 06508 | 52 |
| 9 | 03129 | 03601 | 04108 | 04653 | 05236 | 05858 | 06520 | 51 |
| 10 | 03137 | 03609 | 04117 | 04663 | 05246 | 05869 | 06531 | 50 |
| 11 | 1.03144 | 1.03617 | 1.04126 | 1.04672 | 1.05256 | 1.05879 | 1.06542 | 49 |
| 12 | 03152 | 03625 | 04135 | 04682 | 05266 | 05890 | 06554 | 48 |
| 13 | 03159 | 03633 | 04144 | 04691 | 05276 | 05901 | 06565 | 47 |
| 14 | 03167 | 03642 | 04152 | 04700 | 05286 | 05911 | 06577 | 46 |
| 15 | 03175 | 03650 | 04161 | 04710 | 05297 | 05922 | 06588 | 45 |
| 16 | 03182 | 03658 | 04170 | 04719 | 05307 | 05933 | 06600 | 44 |
| 17 | 03190 | 03666 | 04179 | 04729 | 05317 | 05944 | 06611 | 43 |
| 18 | 03198 | 03674 | 04188 | 04738 | 05327 | 05955 | 06622 | 42 |
| 19 | 03205 | 03683 | 04197 | 04748 | 05337 | 05965 | 06634 | 41 |
| 20 | 03213 | 03691 | 04206 | 04757 | 05347 | 05976 | 06645 | 40 |
| 21 | 1.03221 | 1.03699 | 1.04214 | 1.04767 | 1.05357 | 1.05987 | 1.06657 | 39 |
| 22 | 03228 | 03708 | 04223 | 04776 | 05367 | 05998 | 06668 | 38 |
| 23 | 03236 | 03716 | 04232 | 04786 | 05378 | 06009 | 06680 | 37 |
| 24 | 03244 | 03724 | 04241 | 04795 | 05388 | 06020 | 06691 | 36 |
| 25 | 03251 | 03732 | 04250 | 04805 | 05398 | 06030 | 06703 | 35 |
| 26 | 03259 | 03741 | 04259 | 04815 | 05408 | 06041 | 06715 | 34 |
| 27 | 03267 | 03749 | 04268 | 04824 | 05418 | 06052 | 06726 | 33 |
| 28 | 03275 | 03758 | 04277 | 04834 | 05429 | 06063 | 06738 | 32 |
| 29 | 03282 | 03766 | 04286 | 04843 | 05439 | 06074 | 06749 | 31 |
| 30 | 03290 | 03774 | 04295 | 04853 | 05449 | 06085 | 06761 | 30 |
| 31 | 1.03298 | 1.03783 | 1.04304 | 1.04863 | 1.05460 | 1.06096 | 1.06773 | 29 |
| 32 | 03306 | 03791 | 04313 | 04872 | 05470 | 06107 | 06784 | 28 |
| 33 | 03313 | 03799 | 04322 | 04882 | 05480 | 06118 | 06796 | 27 |
| 34 | 03321 | 03808 | 04331 | 04891 | 05490 | 06129 | 06807 | 26 |
| 35 | 03329 | 03816 | 04340 | 04901 | 05501 | 06140 | 06819 | 25 |
| 36 | 03337 | 03825 | 04349 | 04911 | 05511 | 06151 | 06831 | 24 |
| 37 | 03345 | 03833 | 04358 | 04920 | 05521 | 06162 | 06843 | 23 |
| 38 | 03353 | 03842 | 04367 | 04930 | 05532 | 06173 | 06854 | 22 |
| 39 | 03360 | 03850 | 04376 | 04940 | 05542 | 06184 | 06866 | 21 |
| 40 | 03368 | 03858 | 04385 | 04950 | 05552 | 06195 | 06878 | 20 |
| 41 | 1.03376 | 1.03867 | 1.04394 | 1.04959 | 1.05563 | 1.06206 | 1.06889 | 19 |
| 42 | 03384 | 03875 | 04403 | 04969 | 05573 | 06217 | 06901 | 18 |
| 43 | 03392 | 03884 | 04413 | 04979 | 05584 | 06228 | 06913 | 17 |
| 44 | 03400 | 03892 | 04422 | 04989 | 05594 | 06239 | 06925 | 16 |
| 45 | 03408 | 03901 | 04431 | 04998 | 05604 | 06250 | 06936 | 15 |
| 46 | 03416 | 03909 | 04440 | 05008 | 05615 | 06261 | 06948 | 14 |
| 47 | 03424 | 03918 | 04449 | 05018 | 05625 | 06272 | 06960 | 13 |
| 48 | 03432 | 03927 | 04458 | 05028 | 05636 | 06283 | 06972 | 12 |
| 49 | 03439 | 03935 | 04468 | 05038 | 05646 | 06295 | 06984 | 11 |
| 50 | 03447 | 03944 | 04477 | 05047 | 05657 | 06306 | 06995 | 10 |
| 51 | 1.03455 | 1.03952 | 1.04486 | 1.05057 | 1.05667 | 1.06317 | 1.07007 | 9 |
| 52 | 03463 | 03961 | 04495 | 05067 | 05678 | 06328 | 07019 | 8 |
| 53 | 03471 | 03969 | 04504 | 05077 | 05688 | 06339 | 07031 | 7 |
| 54 | 03479 | 03978 | 04514 | 05087 | 05699 | 06350 | 07043 | 6 |
| 55 | 03487 | 03987 | 04523 | 05097 | 05709 | 06362 | 07055 | 5 |
| 56 | 03495 | 03995 | 04532 | 05107 | 05720 | 06373 | 07067 | 4 |
| 57 | 03503 | 04004 | 04541 | 05116 | 05730 | 06384 | 07079 | 3 |
| 58 | 03512 | 04013 | 04551 | 05126 | 05741 | 06395 | 07091 | 2 |
| 59 | 03520 | 04021 | 04560 | 05136 | 05751 | 06407 | 07103 | 1 |
| 60 | 03528 | 04030 | 04569 | 05146 | 05762 | 06418 | 07115 | 0 |
| ′ | 75° | 74° | 73° | 72° | 71° | 70° | 69° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 21° | 22° | 23° | 24° | 25° | 26° | 27° | |
| 0 | 1.07115 | 1.07853 | 1.08636 | 1.09464 | 1.10338 | 1.11260 | 1.12233 | 60 |
| 1 | 07126 | 07866 | 08649 | 09478 | 10353 | 11276 | 12249 | 59 |
| 2 | 07138 | 07879 | 08663 | 09492 | 10368 | 11292 | 12266 | 58 |
| 3 | 07150 | 07892 | 08676 | 09506 | 10383 | 11308 | 12283 | 57 |
| 4 | 07162 | 07904 | 08690 | 09520 | 10398 | 11323 | 12299 | 56 |
| 5 | 07174 | 07917 | 08703 | 09535 | 10413 | 11339 | 12316 | 55 |
| 6 | 07186 | 07930 | 08717 | 09549 | 10428 | 11355 | 12333 | 54 |
| 7 | 07199 | 07943 | 08730 | 09563 | 10443 | 11371 | 12349 | 53 |
| 8 | 07211 | 07955 | 08744 | 09577 | 10458 | 11387 | 12366 | 52 |
| 9 | 07223 | 07968 | 08757 | 09592 | 10473 | 11403 | 12383 | 51 |
| 10 | 07235 | 07981 | 08771 | 09606 | 10488 | 11419 | 12400 | 50 |
| 11 | 1.07247 | 1.07994 | 1.08784 | 1.09620 | 1.10503 | 1.11435 | 1.12416 | 49 |
| 12 | 07259 | 08006 | 08798 | 09635 | 10518 | 11451 | 12433 | 48 |
| 13 | 07271 | 08019 | 08811 | 09649 | 10533 | 11467 | 12450 | 47 |
| 14 | 07283 | 08032 | 08825 | 09663 | 10549 | 11483 | 12467 | 46 |
| 15 | 07295 | 08045 | 08839 | 09678 | 10564 | 11499 | 12484 | 45 |
| 16 | 07307 | 08058 | 08852 | 09692 | 10579 | 11515 | 12501 | 44 |
| 17 | 07320 | 08071 | 08866 | 09707 | 10594 | 11531 | 12518 | 43 |
| 18 | 07332 | 08084 | 08880 | 09721 | 10609 | 11547 | 12534 | 42 |
| 19 | 07344 | 08097 | 08893 | 09735 | 10625 | 11563 | 12551 | 41 |
| 20 | 07356 | 08109 | 08907 | 09750 | 10640 | 11579 | 12568 | 40 |
| 21 | 1.07368 | 1.08122 | 1.08921 | 1.09764 | 1.10655 | 1.11595 | 1.12585 | 39 |
| 22 | 07380 | 08135 | 08934 | 09779 | 10670 | 11611 | 12602 | 38 |
| 23 | 07393 | 08148 | 08948 | 09793 | 10686 | 11627 | 12619 | 37 |
| 24 | 07405 | 08161 | 08962 | 09808 | 10701 | 11643 | 12636 | 36 |
| 25 | 07417 | 08174 | 08975 | 09822 | 10716 | 11659 | 12653 | 35 |
| 26 | 07429 | 08187 | 08989 | 09837 | 10731 | 11675 | 12670 | 34 |
| 27 | 07442 | 08200 | 09003 | 09851 | 10747 | 11691 | 12687 | 33 |
| 28 | 07454 | 08213 | 09017 | 09866 | 10762 | 11708 | 12704 | 32 |
| 29 | 07466 | 08226 | 09030 | 09880 | 10777 | 11724 | 12721 | 31 |
| 30 | 07479 | 08239 | 09044 | 09895 | 10793 | 11740 | 12738 | 30 |
| 31 | 1.07491 | 1.08252 | 1.09058 | 1.09909 | 1.10808 | 1.11756 | 1.12755 | 29 |
| 32 | 07503 | 08265 | 09072 | 09924 | 10824 | 11772 | 12772 | 28 |
| 33 | 07516 | 08278 | 09086 | 09939 | 10839 | 11789 | 12789 | 27 |
| 34 | 07528 | 08291 | 09099 | 09953 | 10854 | 11805 | 12807 | 26 |
| 35 | 07540 | 08305 | 09113 | 09968 | 10870 | 11821 | 12824 | 25 |
| 36 | 07553 | 08318 | 09127 | 09982 | 10885 | 11838 | 12841 | 24 |
| 37 | 07565 | 08331 | 09141 | 09997 | 10901 | 11854 | 12858 | 23 |
| 38 | 07578 | 08344 | 09155 | 10012 | 10916 | 11870 | 12875 | 22 |
| 39 | 07590 | 08357 | 09169 | 10026 | 10932 | 11886 | 12892 | 21 |
| 40 | 07602 | 08370 | 09183 | 10041 | 10947 | 11903 | 12910 | 20 |
| 41 | 1.07615 | 1.08383 | 1.09197 | 1.10055 | 1.10963 | 1.11919 | 1.12927 | 19 |
| 42 | 07627 | 08397 | 09211 | 10071 | 10978 | 11936 | 12944 | 18 |
| 43 | 07640 | 08410 | 09224 | 10085 | 10994 | 11952 | 12961 | 17 |
| 44 | 07652 | 08423 | 09238 | 10100 | 11009 | 11968 | 12979 | 16 |
| 45 | 07665 | 08436 | 09252 | 10115 | 11025 | 11985 | 12996 | 15 |
| 46 | 07677 | 08449 | 09266 | 10130 | 11041 | 12001 | 13013 | 14 |
| 47 | 07690 | 08463 | 09280 | 10144 | 11056 | 12018 | 13031 | 13 |
| 48 | 07702 | 08476 | 09294 | 10159 | 11072 | 12034 | 13048 | 12 |
| 49 | 07715 | 08489 | 09308 | 10174 | 11087 | 12051 | 13065 | 11 |
| 50 | 07727 | 08503 | 09323 | 10189 | 11103 | 12067 | 13083 | 10 |
| 51 | 1.07740 | 1.08516 | 1.09337 | 1.10204 | 1.11119 | 1.12084 | 1.13100 | 9 |
| 52 | 07752 | 08529 | 09351 | 10218 | 11134 | 12100 | 13117 | 8 |
| 53 | 07765 | 08542 | 09365 | 10233 | 11150 | 12117 | 13135 | 7 |
| 54 | 07778 | 08556 | 09379 | 10248 | 11166 | 12133 | 13152 | 6 |
| 55 | 07790 | 08569 | 09393 | 10263 | 11181 | 12150 | 13170 | 5 |
| 56 | 07803 | 08582 | 09407 | 10278 | 11197 | 12166 | 13187 | 4 |
| 57 | 07816 | 08596 | 09421 | 10293 | 11213 | 12183 | 13205 | 3 |
| 58 | 07828 | 08609 | 09435 | 10308 | 11229 | 12199 | 13222 | 2 |
| 59 | 07841 | 08623 | 09449 | 10323 | 11244 | 12216 | 13240 | 1 |
| 60 | 07853 | 08636 | 09464 | 10338 | 11260 | 12233 | 13257 | 0 |
| ′ | 68° | 67° | 66° | 65° | 64° | 63° | 62° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 28° | 29° | 30° | 31° | 32° | 33° | 34° | |
| 0 | 1.13257 | 1.14335 | 1.15470 | 1.16663 | 1.17918 | 1.19236 | 1.20622 | 60 |
| 1 | 13275 | 14354 | 15489 | 16684 | 17939 | 19259 | 20645 | 59 |
| 2 | 13292 | 14372 | 15509 | 16704 | 17961 | 19281 | 20669 | 58 |
| 3 | 13310 | 14391 | 15528 | 16725 | 17982 | 19304 | 20693 | 57 |
| 4 | 13327 | 14409 | 15548 | 16745 | 18004 | 19327 | 20717 | 56 |
| 5 | 13345 | 14428 | 15567 | 16766 | 18025 | 19349 | 20740 | 55 |
| 6 | 13362 | 14446 | 15587 | 16786 | 18047 | 19372 | 20764 | 54 |
| 7 | 13380 | 14465 | 15606 | 16806 | 18068 | 19394 | 20788 | 53 |
| 8 | 13398 | 14483 | 15626 | 16827 | 18090 | 19417 | 20812 | 52 |
| 9 | 13415 | 14502 | 15645 | 16848 | 18111 | 19440 | 20836 | 51 |
| 10 | 13433 | 14521 | 15665 | 16868 | 18133 | 19463 | 20859 | 50 |
| 11 | 1.13451 | 1.14539 | 1.15684 | 1.16889 | 1.18155 | 1.19485 | 1.20883 | 49 |
| 12 | 13468 | 14558 | 15704 | 16909 | 18176 | 19508 | 20907 | 48 |
| 13 | 13486 | 14576 | 15724 | 16930 | 18198 | 19531 | 20931 | 47 |
| 14 | 13504 | 14595 | 15743 | 16950 | 18220 | 19554 | 20955 | 46 |
| 15 | 13521 | 14614 | 15763 | 16971 | 18241 | 19576 | 20979 | 45 |
| 16 | 13539 | 14632 | 15782 | 16992 | 18263 | 19599 | 21003 | 44 |
| 17 | 13557 | 14651 | 15802 | 17012 | 18285 | 19622 | 21027 | 43 |
| 18 | 13575 | 14670 | 15822 | 17033 | 18307 | 19645 | 21051 | 42 |
| 19 | 13593 | 14689 | 15841 | 17054 | 18328 | 19668 | 21075 | 41 |
| 20 | 13610 | 14707 | 15861 | 17075 | 18350 | 19691 | 21099 | 40 |
| 21 | 1.13628 | 1.14726 | 1.15881 | 1.17095 | 1.18372 | 1.19713 | 1.21123 | 39 |
| 22 | 13646 | 14745 | 15901 | 17116 | 18394 | 19736 | 21147 | 38 |
| 23 | 13664 | 14764 | 15920 | 17137 | 18416 | 19759 | 21171 | 37 |
| 24 | 13682 | 14782 | 15940 | 17158 | 18437 | 19782 | 21195 | 36 |
| 25 | 13700 | 14801 | 15960 | 17178 | 18459 | 19805 | 21220 | 35 |
| 26 | 13718 | 14820 | 15980 | 17199 | 18481 | 19828 | 21244 | 34 |
| 27 | 13735 | 14839 | 16000 | 17220 | 18503 | 19851 | 21268 | 33 |
| 28 | 13753 | 14858 | 16019 | 17241 | 18525 | 19874 | 21292 | 32 |
| 29 | 13771 | 14877 | 16039 | 17262 | 18547 | 19897 | 21316 | 31 |
| 30 | 13789 | 14896 | 16059 | 17283 | 18569 | 19920 | 21341 | 30 |
| 31 | 1.13807 | 1.14914 | 1.16079 | 1.17304 | 1.18591 | 1.19944 | 1.21365 | 29 |
| 32 | 13825 | 14933 | 16099 | 17325 | 18613 | 19967 | 21389 | 28 |
| 33 | 13843 | 14952 | 16119 | 17346 | 18635 | 19990 | 21414 | 27 |
| 34 | 13861 | 14971 | 16139 | 17367 | 18657 | 20013 | 21438 | 26 |
| 35 | 13879 | 14990 | 16159 | 17388 | 18679 | 20036 | 21462 | 25 |
| 36 | 13897 | 15009 | 16179 | 17409 | 18701 | 20059 | 21487 | 24 |
| 37 | 13916 | 15028 | 16199 | 17430 | 18723 | 20083 | 21511 | 23 |
| 38 | 13934 | 15047 | 16219 | 17451 | 18745 | 20106 | 21535 | 22 |
| 39 | 13952 | 15066 | 16239 | 17472 | 18767 | 20129 | 21560 | 21 |
| 40 | 13970 | 15085 | 16259 | 17493 | 18790 | 20152 | 21584 | 20 |
| 41 | 1.13988 | 1.15105 | 1.16279 | 1.17514 | 1.18812 | 1.20176 | 1.21609 | 19 |
| 42 | 14006 | 15124 | 16299 | 17535 | 18834 | 20199 | 21633 | 18 |
| 43 | 14024 | 15143 | 16319 | 17556 | 18856 | 20222 | 21658 | 17 |
| 44 | 14042 | 15162 | 16339 | 17577 | 18878 | 20246 | 21682 | 16 |
| 45 | 14061 | 15181 | 16359 | 17598 | 18901 | 20269 | 21707 | 15 |
| 46 | 14079 | 15200 | 16380 | 17620 | 18923 | 20292 | 21731 | 14 |
| 47 | 14097 | 15219 | 16400 | 17641 | 18945 | 20316 | 21756 | 13 |
| 48 | 14115 | 15239 | 16420 | 17662 | 18967 | 20339 | 21781 | 12 |
| 49 | 14134 | 15258 | 16440 | 17683 | 18990 | 20363 | 21805 | 11 |
| 50 | 14152 | 15277 | 16460 | 17704 | 19012 | 20886 | 21830 | 10 |
| 51 | 1.14170 | 1.15296 | 1.16481 | 1.17726 | 1.19034 | 1.20410 | 1.21855 | 9 |
| 52 | 14188 | 15315 | 16501 | 17747 | 19057 | 20433 | 21879 | 8 |
| 53 | 14207 | 15335 | 16521 | 17768 | 19079 | 20457 | 21904 | 7 |
| 54 | 14225 | 15354 | 16541 | 17790 | 19102 | 20480 | 21929 | 6 |
| 55 | 14243 | 15373 | 16562 | 17811 | 19124 | 20504 | 21953 | 5 |
| 56 | 14262 | 15393 | 16582 | 17832 | 19146 | 20527 | 21978 | 4 |
| 57 | 14280 | 15412 | 16602 | 17854 | 19169 | 20551 | 22003 | 3 |
| 58 | 14209 | 15431 | 16623 | 17875 | 19191 | 20575 | 22028 | 2 |
| 59 | 14317 | 15451 | 16643 | 17896 | 19214 | 20598 | 22053 | 1 |
| 60 | 14335 | 15470 | 16663 | 17918 | 19236 | 20622 | 22077 | 0 |
| ′ | 61° | 60° | 59° | 58° | 57° | 56° | 55° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 35° | 36° | 37° | 38° | 39° | 40° | 41° | |
| 0 | 1.22077 | 1.23607 | 1.25214 | 1.26902 | 1.28676 | 1.30541 | 1.32501 | 60 |
| 1 | 22102 | 23633 | 25241 | 26931 | 28706 | 30573 | 32535 | 59 |
| 2 | 22127 | 23659 | 25269 | 26960 | 28737 | 30605 | 32568 | 58 |
| 3 | 22152 | 23685 | 25296 | 26988 | 28767 | 30636 | 32602 | 57 |
| 4 | 22177 | 23711 | 25324 | 27017 | 28797 | 30668 | 32636 | 56 |
| 5 | 22202 | 23738 | 25351 | 27046 | 28828 | 30700 | 32669 | 55 |
| 6 | 22227 | 23764 | 25379 | 27075 | 28858 | 30732 | 32703 | 54 |
| 7 | 22252 | 23790 | 25406 | 27104 | 28889 | 30764 | 32737 | 53 |
| 8 | 22277 | 23816 | 25434 | 27133 | 28919 | 30796 | 32770 | 52 |
| 9 | 22302 | 23843 | 25462 | 27162 | 28950 | 30829 | 32804 | 51 |
| 10 | 22327 | 23869 | 25489 | 27191 | 28980 | 30861 | 32838 | 50 |
| 11 | 1.22352 | 1.23895 | 1.25517 | 1.27221 | 1.29011 | 1.30893 | 1.32872 | 49 |
| 12 | 22377 | 23922 | 25545 | 27250 | 29042 | 30925 | 32905 | 48 |
| 13 | 22402 | 23948 | 25572 | 27279 | 29072 | 30957 | 32939 | 47 |
| 14 | 22428 | 23975 | 25600 | 27308 | 29103 | 30989 | 32973 | 46 |
| 15 | 22453 | 24001 | 25628 | 27337 | 29133 | 31022 | 33007 | 45 |
| 16 | 22478 | 24028 | 25656 | 27366 | 29164 | 31054 | 33041 | 44 |
| 17 | 22503 | 24054 | 25683 | 27396 | 29195 | 31086 | 33075 | 43 |
| 18 | 22528 | 24081 | 25711 | 27425 | 29226 | 31119 | 33109 | 42 |
| 19 | 22554 | 24107 | 25739 | 27454 | 29256 | 31151 | 33143 | 41 |
| 20 | 22579 | 24134 | 25767 | 27483 | 29287 | 31183 | 33177 | 40 |
| 21 | 1.22604 | 1.24160 | 1.25795 | 1.27513 | 1.29318 | 1.31216 | 1.33211 | 39 |
| 22 | 22629 | 24187 | 25823 | 27542 | 29349 | 31248 | 33245 | 38 |
| 23 | 22655 | 24213 | 25851 | 27572 | 29380 | 31281 | 33279 | 37 |
| 24 | 22680 | 24240 | 25879 | 27601 | 29411 | 31313 | 33314 | 36 |
| 25 | 22706 | 24267 | 25907 | 27630 | 29442 | 31346 | 33348 | 35 |
| 26 | 22731 | 24293 | 25935 | 27660 | 29473 | 31378 | 33382 | 34 |
| 27 | 22756 | 24320 | 25963 | 27689 | 29504 | 31411 | 33416 | 33 |
| 28 | 22782 | 24347 | 25991 | 27719 | 29535 | 31443 | 33451 | 32 |
| 29 | 22807 | 24373 | 26019 | 27748 | 29566 | 31476 | 33485 | 31 |
| 30 | 22833 | 24400 | 26047 | 27778 | 29597 | 31509 | 33519 | 30 |
| 31 | 1.22858 | 1.24427 | 1.26075 | 1.27807 | 1.29628 | 1.31541 | 1.33554 | 29 |
| 32 | 22884 | 24454 | 26104 | 27837 | 29659 | 31574 | 33588 | 28 |
| 33 | 22909 | 24481 | 26132 | 27867 | 29690 | 31607 | 33622 | 27 |
| 34 | 22935 | 24508 | 26160 | 27896 | 29721 | 31640 | 33657 | 26 |
| 35 | 22960 | 24534 | 26188 | 27926 | 29752 | 31672 | 33691 | 25 |
| 36 | 22986 | 24561 | 26216 | 27956 | 29784 | 31705 | 33726 | 24 |
| 37 | 23012 | 24588 | 26245 | 27985 | 29815 | 31738 | 33760 | 23 |
| 38 | 23037 | 24615 | 26273 | 28015 | 29846 | 31771 | 33795 | 22 |
| 39 | 23063 | 24642 | 26301 | 28045 | 29877 | 31804 | 33830 | 21 |
| 40 | 23089 | 24669 | 26330 | 28075 | 29909 | 31837 | 33864 | 20 |
| 41 | 1.23114 | 1.24696 | 1.26358 | 1.28105 | 1.29940 | 1.31870 | 1.33899 | 19 |
| 42 | 23140 | 24723 | 26387 | 28134 | 29971 | 31903 | 33934 | 18 |
| 43 | 23166 | 24750 | 26415 | 28164 | 30003 | 31936 | 33968 | 17 |
| 44 | 23192 | 24777 | 26443 | 28194 | 30034 | 31969 | 34003 | 16 |
| 45 | 23217 | 24804 | 26472 | 28224 | 30066 | 32002 | 34038 | 15 |
| 46 | 23243 | 24832 | 26500 | 28254 | 30097 | 32035 | 34073 | 14 |
| 47 | 23269 | 24859 | 26529 | 28284 | 30129 | 32068 | 34108 | 13 |
| 48 | 23295 | 24886 | 26557 | 28314 | 30160 | 32101 | 34142 | 12 |
| 49 | 23321 | 24913 | 26586 | 28344 | 30192 | 32134 | 34177 | 11 |
| 50 | 23347 | 24940 | 26615 | 28374 | 30223 | 32168 | 34212 | 10 |
| 51 | 1.23373 | 1.24967 | 1.26643 | 1.28404 | 1.30255 | 1.32201 | 1.34247 | 9 |
| 52 | 23399 | 24995 | 26672 | 28434 | 30287 | 32234 | 34282 | 8 |
| 53 | 23424 | 25022 | 26701 | 28464 | 30318 | 32267 | 34317 | 7 |
| 54 | 23450 | 25049 | 26729 | 28495 | 30350 | 32301 | 34352 | 6 |
| 55 | 23476 | 25077 | 26758 | 28525 | 30382 | 32334 | 34387 | 5 |
| 56 | 23502 | 25104 | 26787 | 28555 | 30413 | 32368 | 34423 | 4 |
| 57 | 23529 | 25131 | 26815 | 28585 | 30445 | 32401 | 34458 | 3 |
| 58 | 23555 | 25159 | 26844 | 28615 | 30477 | 32434 | 34493 | 2 |
| 59 | 23581 | 25186 | 26873 | 28646 | 30509 | 32468 | 34528 | 1 |
| 60 | 23607 | 25214 | 26902 | 28676 | 30541 | 32501 | 34563 | 0 |
| ′ | 54° | 53° | 52° | 51° | 50° | 49° | 48° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 42° | 43° | 44° | 45° | 46° | 47° | 48° | |
| 0 | 1.34563 | 1.36733 | 1.39016 | 1.41421 | 1.43956 | 1.46628 | 1.49448 | 60 |
| 1 | 34599 | 36770 | 39055 | 41463 | 43999 | 46674 | 49496 | 59 |
| 2 | 34634 | 36807 | 39095 | 41504 | 44042 | 46719 | 49544 | 58 |
| 3 | 34669 | 36844 | 39134 | 41545 | 44086 | 46765 | 49593 | 57 |
| 4 | 34704 | 36881 | 39173 | 41586 | 44129 | 46811 | 49641 | 56 |
| 5 | 34740 | 36919 | 39212 | 41627 | 44173 | 46857 | 49690 | 55 |
| 6 | 34775 | 36956 | 39251 | 41669 | 44217 | 46903 | 49738 | 54 |
| 7 | 34811 | 36993 | 39291 | 41710 | 44260 | 46949 | 49787 | 53 |
| 8 | 34846 | 37030 | 39330 | 41752 | 44304 | 46995 | 49835 | 52 |
| 9 | 34882 | 37068 | 39369 | 41793 | 44347 | 47041 | 49884 | 51 |
| 10 | 34917 | 37105 | 39409 | 41835 | 44391 | 47087 | 49933 | 50 |
| 11 | 1.34953 | 1.37143 | 1.39448 | 1.41876 | 1.44435 | 1.47134 | 1.49981 | 49 |
| 12 | 34988 | 37180 | 39487 | 41918 | 44479 | 47180 | 50030 | 48 |
| 13 | 35024 | 37218 | 39527 | 41959 | 44523 | 47226 | 50079 | 47 |
| 14 | 35060 | 37255 | 39566 | 42001 | 44567 | 47272 | 50128 | 46 |
| 15 | 35095 | 37293 | 39606 | 42042 | 44610 | 47319 | 50177 | 45 |
| 16 | 35131 | 37330 | 39646 | 42084 | 44654 | 47365 | 50226 | 44 |
| 17 | 35167 | 37368 | 39685 | 42126 | 44698 | 47411 | 50275 | 43 |
| 18 | 35203 | 37406 | 39725 | 42168 | 44742 | 47458 | 50324 | 42 |
| 19 | 35238 | 37443 | 39764 | 42210 | 44787 | 47504 | 50373 | 41 |
| 20 | 35274 | 37481 | 39804 | 42251 | 44831 | 47551 | 50422 | 40 |
| 21 | 1.35310 | 1.37519 | 1.39844 | 1.42293 | 1.44875 | 1.47598 | 1.50471 | 39 |
| 22 | 35346 | 37556 | 39884 | 42335 | 44919 | 47644 | 50521 | 38 |
| 23 | 35382 | 37594 | 39924 | 42377 | 44963 | 47691 | 50570 | 37 |
| 24 | 35418 | 37632 | 39963 | 42419 | 45007 | 47738 | 50619 | 36 |
| 25 | 35454 | 37670 | 40003 | 42461 | 45052 | 47784 | 50669 | 35 |
| 26 | 35490 | 37708 | 40043 | 42503 | 45096 | 47831 | 50718 | 34 |
| 27 | 35526 | 37746 | 40083 | 42545 | 45141 | 47878 | 50767 | 33 |
| 28 | 35562 | 37784 | 40123 | 42587 | 45185 | 47925 | 50817 | 32 |
| 29 | 35598 | 37822 | 40163 | 42630 | 45229 | 47972 | 50866 | 31 |
| 30 | 35634 | 37860 | 40203 | 42672 | 45274 | 48019 | 50916 | 30 |
| 31 | 1.35670 | 1.37898 | 1.40243 | 1.42714 | 1.45319 | 1.48066 | 1.50966 | 29 |
| 32 | 35707 | 37936 | 40283 | 42756 | 45363 | 48113 | 51015 | 28 |
| 33 | 35743 | 37974 | 40324 | 42799 | 45408 | 48160 | 51065 | 27 |
| 34 | 35779 | 38012 | 40364 | 42841 | 45452 | 48207 | 51115 | 26 |
| 35 | 35815 | 38051 | 40404 | 42883 | 45497 | 48254 | 51165 | 25 |
| 36 | 35852 | 38089 | 40444 | 42926 | 45542 | 48301 | 51215 | 24 |
| 37 | 35888 | 38127 | 40485 | 42968 | 45587 | 48349 | 51265 | 23 |
| 38 | 35924 | 38165 | 40525 | 43011 | 45631 | 48396 | 51314 | 22 |
| 39 | 35961 | 38204 | 40565 | 43053 | 45676 | 48443 | 51364 | 21 |
| 40 | 35997 | 38242 | 40606 | 43096 | 45721 | 48491 | 51415 | 20 |
| 41 | 1.36034 | 1.38280 | 1.40646 | 1.43139 | 1.45766 | 1.48538 | 1.51465 | 19 |
| 42 | 36070 | 38319 | 40687 | 43181 | 45811 | 48586 | 51515 | 18 |
| 43 | 36107 | 38357 | 40727 | 43224 | 45856 | 48633 | 51565 | 17 |
| 44 | 36143 | 38396 | 40768 | 43267 | 45901 | 48681 | 51615 | 16 |
| 45 | 36180 | 38434 | 40808 | 43310 | 45946 | 48728 | 51665 | 15 |
| 46 | 36217 | 38473 | 40849 | 43352 | 45992 | 48776 | 51716 | 14 |
| 47 | 36253 | 38512 | 40890 | 43395 | 46037 | 48824 | 51766 | 13 |
| 48 | 36290 | 38550 | 40930 | 43438 | 46082 | 48871 | 51817 | 12 |
| 49 | 36327 | 38589 | 40971 | 43481 | 46127 | 48919 | 51867 | 11 |
| 50 | 36363 | 38628 | 41012 | 43524 | 46173 | 48967 | 51918 | 10 |
| 51 | 1.36400 | 1.38666 | 1.41053 | 1.43567 | 1.46218 | 1.49015 | 1.51968 | 9 |
| 52 | 36437 | 38705 | 41093 | 43610 | 46263 | 49063 | 52019 | 8 |
| 53 | 36474 | 38744 | 41134 | 43653 | 46309 | 49111 | 52069 | 7 |
| 54 | 36511 | 38783 | 41175 | 43696 | 46354 | 49159 | 52120 | 6 |
| 55 | 36548 | 38822 | 41216 | 43739 | 46400 | 49207 | 52171 | 5 |
| 56 | 36585 | 38860 | 41257 | 43783 | 46445 | 49255 | 52222 | 4 |
| 57 | 36622 | 38899 | 41298 | 43826 | 46491 | 49303 | 52273 | 3 |
| 58 | 36659 | 38938 | 41339 | 43869 | 46537 | 49351 | 52323 | 2 |
| 59 | 36696 | 38977 | 41380 | 43912 | 46582 | 49399 | 52374 | 1 |
| 60 | 36733 | 39016 | 41421 | 43956 | 46628 | 49448 | 52425 | 0 |
| ′ | 47° | 46° | 45° | 44° | 43° | 42° | 41° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 49° | 50° | 51° | 52° | 53° | 54° | 55° | |
| 0 | 1.52425 | 1.55572 | 1.58902 | 1.62427 | 1.66164 | 1.70130 | 1.74345 | 60 |
| 1 | 52476 | 55626 | 58959 | 62487 | 66228 | 70198 | 74417 | 59 |
| 2 | 52527 | 55680 | 59016 | 62548 | 66292 | 70267 | 74490 | 58 |
| 3 | 52579 | 55734 | 59073 | 62609 | 66357 | 70335 | 74562 | 57 |
| 4 | 52630 | 55789 | 59130 | 62669 | 66421 | 70403 | 74635 | 56 |
| 5 | 52681 | 55843 | 59188 | 62730 | 66486 | 70472 | 74708 | 55 |
| 6 | 52732 | 55897 | 59245 | 62791 | 66550 | 70540 | 74781 | 54 |
| 7 | 52784 | 55951 | 59302 | 62852 | 66615 | 70609 | 74854 | 53 |
| 8 | 52835 | 56005 | 59360 | 62913 | 66679 | 70677 | 74927 | 52 |
| 9 | 52886 | 56060 | 59418 | 62974 | 66744 | 70746 | 75000 | 51 |
| 10 | 52938 | 56114 | 59475 | 63035 | 66809 | 70815 | 75073 | 50 |
| 11 | 1.52989 | 1.56169 | 1.59533 | 1.63096 | 1.66873 | 1.70884 | 1.75146 | 49 |
| 12 | 53041 | 56223 | 59590 | 63157 | 66938 | 70953 | 75219 | 48 |
| 13 | 53092 | 56278 | 59648 | 63218 | 67003 | 71022 | 75293 | 47 |
| 14 | 53144 | 56332 | 59706 | 63279 | 67068 | 71091 | 75366 | 46 |
| 15 | 53196 | 56387 | 59764 | 63341 | 67133 | 71160 | 75440 | 45 |
| 16 | 53247 | 56442 | 59822 | 63402 | 67199 | 71229 | 75513 | 44 |
| 17 | 53299 | 56497 | 59880 | 63464 | 67264 | 71298 | 75587 | 43 |
| 18 | 53351 | 56551 | 59938 | 63525 | 67329 | 71368 | 75661 | 42 |
| 19 | 53403 | 56606 | 59996 | 63587 | 67394 | 71437 | 75734 | 41 |
| 20 | 53455 | 56661 | 60054 | 63648 | 67460 | 71506 | 75808 | 40 |
| 21 | 1.53507 | 1.56716 | 1.60112 | 1.63710 | 1.67525 | 1.71576 | 1.75882 | 39 |
| 22 | 53559 | 56771 | 60171 | 63772 | 67591 | 71646 | 75956 | 38 |
| 23 | 53611 | 56826 | 60229 | 63834 | 67656 | 71715 | 76031 | 37 |
| 24 | 53663 | 56881 | 60287 | 63895 | 67722 | 71785 | 76105 | 36 |
| 25 | 53715 | 56937 | 60346 | 63957 | 67788 | 71855 | 76179 | 35 |
| 26 | 53768 | 56992 | 60404 | 64019 | 67853 | 71925 | 76253 | 34 |
| 27 | 53820 | 57047 | 60463 | 64081 | 67919 | 71995 | 76328 | 33 |
| 28 | 53872 | 57103 | 60521 | 64144 | 67985 | 72065 | 76402 | 32 |
| 29 | 53924 | 57158 | 60580 | 64206 | 68051 | 72135 | 76477 | 31 |
| 30 | 53977 | 57213 | 60639 | 64268 | 68117 | 72205 | 76552 | 30 |
| 31 | 1.54029 | 1.57269 | 1.60698 | 1.64330 | 1.68183 | 1.72275 | 1.76626 | 29 |
| 32 | 54082 | 57324 | 60756 | 64393 | 68250 | 72346 | 76701 | 28 |
| 33 | 54134 | 57380 | 60815 | 64455 | 68316 | 72416 | 76776 | 27 |
| 34 | 54187 | 57436 | 60874 | 64518 | 68382 | 72487 | 76851 | 26 |
| 35 | 54240 | 57491 | 60933 | 64580 | 68449 | 72557 | 76926 | 25 |
| 36 | 54292 | 57547 | 60992 | 64643 | 68515 | 72628 | 77001 | 24 |
| 37 | 54345 | 57603 | 61051 | 64705 | 68582 | 72698 | 77077 | 23 |
| 38 | 54398 | 57659 | 61111 | 64768 | 68648 | 72769 | 77152 | 22 |
| 39 | 54451 | 57715 | 61170 | 64831 | 68715 | 72840 | 77227 | 21 |
| 40 | 54504 | 57771 | 61229 | 64894 | 68782 | 72911 | 77303 | 20 |
| 41 | 1.54557 | 1.57827 | 1.61288 | 1.64957 | 1.68848 | 1.72982 | 1.77378 | 19 |
| 42 | 54610 | 57883 | 61348 | 65020 | 68915 | 73053 | 77454 | 18 |
| 43 | 54663 | 57939 | 61407 | 65083 | 68982 | 73124 | 77530 | 17 |
| 44 | 54716 | 57995 | 61467 | 65146 | 69049 | 73195 | 77606 | 16 |
| 45 | 54769 | 58051 | 61526 | 65209 | 69116 | 73267 | 77681 | 15 |
| 46 | 54822 | 58108 | 61586 | 65272 | 69183 | 73338 | 77757 | 14 |
| 47 | 54876 | 58164 | 61646 | 65336 | 69250 | 73409 | 77833 | 13 |
| 48 | 54929 | 58221 | 61705 | 65399 | 69318 | 73481 | 77910 | 12 |
| 49 | 54982 | 58277 | 61765 | 65462 | 69385 | 73552 | 77986 | 11 |
| 50 | 55036 | 58333 | 61825 | 65526 | 69452 | 73624 | 78062 | 10 |
| 51 | 1.55089 | 1.58390 | 1.61885 | 1.65589 | 1.69520 | 1.73696 | 1.78138 | 9 |
| 52 | 55143 | 58447 | 61945 | 65653 | 69587 | 73768 | 78215 | 8 |
| 53 | 55196 | 58503 | 62005 | 65717 | 69655 | 73840 | 78291 | 7 |
| 54 | 55250 | 58560 | 62065 | 65780 | 69723 | 73911 | 78368 | 6 |
| 55 | 55303 | 58617 | 62125 | 65844 | 69790 | 73983 | 78445 | 5 |
| 56 | 55357 | 58674 | 62185 | 65908 | 69858 | 74056 | 78521 | 4 |
| 57 | 55411 | 58731 | 62246 | 65972 | 69926 | 74128 | 78598 | 3 |
| 58 | 55465 | 58788 | 62306 | 66036 | 69994 | 74200 | 78675 | 2 |
| 59 | 55518 | 58845 | 62366 | 66100 | 70062 | 74272 | 78752 | 1 |
| 60 | 55572 | 58902 | 62427 | 66164 | 70130 | 74345 | 78829 | 0 |
| ′ | 40° | 39° | 38° | 37° | 36° | 35° | 34° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 56° | 57° | 58° | 59° | 60° | 61° | 62° | |
| 0 | 1.78829 | 1.83608 | 1.88708 | 1.94160 | 2.00000 | 2.06267 | 2.13005 | 60 |
| 1 | 78906 | 83690 | 88796 | 94254 | 00101 | 06375 | 13122 | 59 |
| 2 | 78984 | 83773 | 88884 | 94349 | 00202 | 06483 | 13239 | 58 |
| 3 | 79061 | 83855 | 88972 | 94443 | 00303 | 06592 | 13356 | 57 |
| 4 | 79138 | 83938 | 89060 | 94537 | 00404 | 06701 | 13473 | 56 |
| 5 | 79216 | 84020 | 89148 | 94632 | 00505 | 06809 | 13590 | 55 |
| 6 | 79293 | 84103 | 89237 | 94726 | 00607 | 06918 | 13707 | 54 |
| 7 | 79371 | 84186 | 89325 | 94821 | 00708 | 07027 | 13825 | 53 |
| 8 | 79449 | 84269 | 89414 | 94916 | 00810 | 07137 | 13942 | 52 |
| 9 | 79527 | 84352 | 89503 | 95011 | 00912 | 07246 | 14060 | 51 |
| 10 | 79604 | 84435 | 89591 | 95106 | 01014 | 07356 | 14178 | 50 |
| 11 | 1.79682 | 1.84518 | 1.89680 | 1.95201 | 2.01116 | 2.07465 | 2.14296 | 49 |
| 12 | 79761 | 84601 | 89769 | 95296 | 01218 | 07575 | 14414 | 48 |
| 13 | 79839 | 84685 | 89858 | 95392 | 01320 | 07685 | 14533 | 47 |
| 14 | 79917 | 84768 | 89948 | 95487 | 01422 | 07795 | 14651 | 46 |
| 15 | 79995 | 84852 | 90037 | 95583 | 01525 | 07905 | 14770 | 45 |
| 16 | 80074 | 84935 | 90126 | 95678 | 01628 | 08015 | 14889 | 44 |
| 17 | 80152 | 85019 | 90216 | 95774 | 01730 | 08126 | 15008 | 43 |
| 18 | 80231 | 85103 | 90305 | 95870 | 01833 | 08236 | 15127 | 42 |
| 19 | 80309 | 85187 | 90395 | 95966 | 01936 | 08347 | 15246 | 41 |
| 20 | 80388 | 85271 | 90485 | 96062 | 02039 | 08458 | 15366 | 40 |
| 21 | 1.80467 | 1.85355 | 1.90575 | 1.96158 | 2.02143 | 2.08569 | 2.15485 | 39 |
| 22 | 80546 | 85439 | 90665 | 96255 | 02246 | 08680 | 15605 | 38 |
| 23 | 80625 | 85523 | 90755 | 96351 | 02349 | 08791 | 15725 | 37 |
| 24 | 80704 | 85608 | 90845 | 96448 | 02453 | 08903 | 15845 | 36 |
| 25 | 80783 | 85692 | 90935 | 96544 | 02557 | 09014 | 15965 | 35 |
| 26 | 80862 | 85777 | 91026 | 96641 | 02661 | 09126 | 16085 | 34 |
| 27 | 80942 | 85861 | 91116 | 96738 | 02765 | 09238 | 16206 | 33 |
| 28 | 81021 | 85946 | 91207 | 96835 | 02869 | 09350 | 16326 | 32 |
| 29 | 81101 | 86031 | 91297 | 96932 | 02973 | 09462 | 16447 | 31 |
| 30 | 81180 | 86116 | 91388 | 97029 | 03077 | 09574 | 16568 | 30 |
| 31 | 1.81260 | 1.86201 | 1.91479 | 1.97127 | 2.03182 | 2.09686 | 2.16689 | 29 |
| 32 | 81340 | 86286 | 91570 | 97224 | 03286 | 09799 | 16810 | 28 |
| 33 | 81419 | 86371 | 91661 | 97322 | 03391 | 09911 | 16932 | 27 |
| 34 | 81499 | 86457 | 91752 | 97420 | 03496 | 10024 | 17053 | 26 |
| 35 | 81579 | 86542 | 91844 | 97517 | 03601 | 10137 | 17175 | 25 |
| 36 | 81659 | 86627 | 91935 | 97615 | 03706 | 10250 | 17297 | 24 |
| 37 | 81740 | 86713 | 92027 | 97713 | 03811 | 10363 | 17419 | 23 |
| 38 | 81820 | 86799 | 92118 | 97811 | 03916 | 10477 | 17541 | 22 |
| 39 | 81900 | 86885 | 92210 | 97910 | 04022 | 10590 | 17663 | 21 |
| 40 | 81981 | 86990 | 92302 | 98008 | 04128 | 10704 | 17786 | 20 |
| 41 | 1.82061 | 1.87056 | 1.92394 | 1.98107 | 2.04233 | 2.10817 | 2.17909 | 19 |
| 42 | 82142 | 87142 | 92486 | 98205 | 04339 | 10931 | 18031 | 18 |
| 43 | 82222 | 87229 | 92578 | 98304 | 04445 | 11045 | 18154 | 17 |
| 44 | 82303 | 87315 | 92670 | 98403 | 04551 | 11159 | 18277 | 16 |
| 45 | 82384 | 87401 | 92762 | 98502 | 04658 | 11274 | 18401 | 15 |
| 46 | 82465 | 87488 | 92855 | 98601 | 04764 | 11388 | 18524 | 14 |
| 47 | 82546 | 87574 | 92947 | 98700 | 04870 | 11503 | 18648 | 13 |
| 48 | 82627 | 87661 | 93040 | 98799 | 04977 | 11617 | 18772 | 12 |
| 49 | 82709 | 87748 | 93133 | 98899 | 05084 | 11732 | 18896 | 11 |
| 50 | 82790 | 87834 | 93226 | 98998 | 05191 | 11847 | 19019 | 10 |
| 51 | 1.82871 | 1.87921 | 1.93319 | 1.99098 | 2.05298 | 2.11963 | 2.19144 | 9 |
| 52 | 82953 | 88008 | 93412 | 99198 | 05405 | 12078 | 19268 | 8 |
| 53 | 83034 | 88095 | 93505 | 99298 | 05512 | 12193 | 19393 | 7 |
| 54 | 83116 | 88183 | 93598 | 99398 | 05619 | 12309 | 19517 | 6 |
| 55 | 83198 | 88270 | 93692 | 99498 | 05727 | 12425 | 19642 | 5 |
| 56 | 83280 | 88357 | 93785 | 99598 | 05835 | 12540 | 19767 | 4 |
| 57 | 83362 | 88445 | 93879 | 99698 | 05942 | 12657 | 19892 | 3 |
| 58 | 83444 | 88532 | 93973 | 99799 | 06050 | 12773 | 20018 | 2 |
| 59 | 83526 | 88620 | 94066 | 99899 | 06158 | 12889 | 20143 | 1 |
| 60 | 83608 | 88708 | 94160 | 2.00000 | 06267 | 13005 | 20269 | 0 |
| ′ | 33° | 32° | 31° | 30° | 29° | 28° | 27° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 63° | 64° | 65° | 66° | 67° | 68° | 69° | |
| 0 | 2.20269 | 2.28117 | 2.36620 | 2.45859 | 2.55930 | 2.66947 | 2.79043 | 60 |
| 1 | 20395 | 28253 | 36768 | 46020 | 56106 | 67139 | 79254 | 59 |
| 2 | 20521 | 28390 | 36916 | 46181 | 56282 | 67332 | 79466 | 58 |
| 3 | 20647 | 28526 | 37064 | 46342 | 56458 | 67525 | 79679 | 57 |
| 4 | 20773 | 28663 | 37212 | 46504 | 56634 | 67718 | 79891 | 56 |
| 5 | 20900 | 28800 | 37361 | 46665 | 56811 | 67911 | 80104 | 55 |
| 6 | 21026 | 28937 | 37509 | 46827 | 56988 | 68105 | 80318 | 54 |
| 7 | 21153 | 29074 | 37658 | 46989 | 57165 | 68299 | 80531 | 53 |
| 8 | 21280 | 29211 | 37808 | 47152 | 57342 | 68494 | 80746 | 52 |
| 9 | 21407 | 29349 | 37957 | 47314 | 57520 | 68089 | 80960 | 51 |
| 10 | 21535 | 29487 | 38107 | 47477 | 57698 | 68884 | 81175 | 50 |
| 11 | 2.21662 | 2.29625 | 2.38256 | 2.47640 | 2.57876 | 2.69079 | 2.81390 | 49 |
| 12 | 21790 | 29763 | 38406 | 47804 | 58054 | 69275 | 81605 | 48 |
| 13 | 21918 | 29901 | 38556 | 47967 | 58233 | 69471 | 81821 | 47 |
| 14 | 22045 | 30040 | 38707 | 48131 | 58412 | 69667 | 82037 | 46 |
| 15 | 22174 | 30179 | 38857 | 48295 | 58591 | 69864 | 82254 | 45 |
| 16 | 22302 | 30318 | 39008 | 48459 | 58771 | 70061 | 82471 | 44 |
| 17 | 22430 | 30457 | 39159 | 48624 | 58950 | 70258 | 82688 | 43 |
| 18 | 22559 | 30596 | 39311 | 48789 | 59130 | 70455 | 82906 | 42 |
| 19 | 22688 | 30735 | 39462 | 48954 | 59311 | 70653 | 83124 | 41 |
| 20 | 22817 | 30875 | 39614 | 49119 | 59491 | 70851 | 83342 | 40 |
| 21 | 2.22946 | 2.31015 | 2.39766 | 2.49284 | 2.59672 | 2.71050 | 2.83561 | 39 |
| 22 | 23075 | 31155 | 39918 | 49450 | 59853 | 71249 | 83780 | 38 |
| 23 | 23205 | 31295 | 40070 | 49616 | 60035 | 71448 | 83999 | 37 |
| 24 | 23334 | 31436 | 40222 | 49782 | 60217 | 71647 | 84219 | 36 |
| 25 | 23464 | 31576 | 40375 | 49948 | 60399 | 71847 | 84439 | 35 |
| 26 | 23594 | 31717 | 40528 | 50115 | 60581 | 72047 | 84659 | 34 |
| 27 | 23724 | 31858 | 40681 | 50282 | 60763 | 72247 | 84880 | 33 |
| 28 | 23855 | 31999 | 40835 | 50449 | 60946 | 72448 | 85102 | 32 |
| 29 | 23985 | 32140 | 40988 | 50617 | 61129 | 72649 | 85323 | 31 |
| 30 | 24116 | 32282 | 41142 | 50784 | 61313 | 72850 | 85545 | 30 |
| 31 | 2.24247 | 2.32424 | 2.41296 | 2.50952 | 2.61496 | 2.73052 | 2.85767 | 29 |
| 32 | 24378 | 32566 | 41450 | 51120 | 61680 | 73254 | 85990 | 28 |
| 33 | 24509 | 32708 | 41605 | 51289 | 61864 | 73456 | 86213 | 27 |
| 34 | 24640 | 32850 | 41760 | 51457 | 62049 | 73659 | 86437 | 26 |
| 35 | 24772 | 32993 | 41914 | 51626 | 62234 | 73862 | 86661 | 25 |
| 36 | 24903 | 33135 | 42070 | 51795 | 62419 | 74065 | 86885 | 24 |
| 37 | 25035 | 33278 | 42225 | 51965 | 62604 | 74269 | 87109 | 23 |
| 38 | 25167 | 33422 | 42380 | 52134 | 62790 | 74473 | 87334 | 22 |
| 39 | 25300 | 33565 | 42536 | 52304 | 62976 | 74677 | 87560 | 21 |
| 40 | 25432 | 33708 | 42692 | 52474 | 63162 | 74881 | 87785 | 20 |
| 41 | 2.25565 | 2.33852 | 2.42848 | 2.52645 | 2.63348 | 2.75086 | 2.88011 | 19 |
| 42 | 25697 | 33996 | 43005 | 52815 | 63535 | 75292 | 88238 | 18 |
| 43 | 25830 | 34140 | 43162 | 52986 | 63722 | 75497 | 88465 | 17 |
| 44 | 25963 | 34284 | 43318 | 53157 | 63909 | 75703 | 88692 | 16 |
| 45 | 26097 | 34429 | 43476 | 53329 | 64097 | 75909 | 88920 | 15 |
| 46 | 26230 | 34573 | 43633 | 53500 | 64285 | 76116 | 89148 | 14 |
| 47 | 26364 | 34718 | 43790 | 53672 | 64473 | 76323 | 89376 | 13 |
| 48 | 26498 | 34863 | 43948 | 53845 | 64662 | 76530 | 89605 | 12 |
| 49 | 26632 | 35009 | 44106 | 54017 | 64851 | 76737 | 89834 | 11 |
| 50 | 26766 | 35154 | 44264 | 54190 | 65040 | 76945 | 90063 | 10 |
| 51 | 2.26900 | 2.35300 | 2.44423 | 2.54363 | 2.65229 | 2.77154 | 2.90293 | 9 |
| 52 | 27035 | 35446 | 44582 | 54536 | 65419 | 77362 | 90524 | 8 |
| 53 | 27169 | 35592 | 44741 | 54709 | 65609 | 77571 | 90754 | 7 |
| 54 | 27304 | 35738 | 44900 | 54883 | 65799 | 77780 | 90986 | 6 |
| 55 | 27439 | 35885 | 45059 | 55057 | 65989 | 77990 | 91217 | 5 |
| 56 | 27574 | 36031 | 45219 | 55231 | 66180 | 78200 | 91449 | 4 |
| 57 | 27710 | 36178 | 45378 | 55405 | 66371 | 78410 | 91681 | 3 |
| 58 | 27845 | 36325 | 45539 | 55580 | 66563 | 78621 | 91914 | 2 |
| 59 | 27981 | 36473 | 45699 | 55755 | 66755 | 78832 | 92147 | 1 |
| 60 | 28117 | 36620 | 45859 | 55930 | 66947 | 79043 | 92380 | 0 |
| ′ | 26° | 25° | 24° | 23° | 22° | 21° | 20° | ′ |
| | COSECANTS | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 70° | 71° | 72° | 73° | 74° | 75° | 76° | |
| 0 | 2.92380 | 3.07155 | 3.23607 | 3.42030 | 3.62796 | 3.86370 | 4.13357 | 60 |
| 1 | 92614 | 07415 | 23897 | 42356 | 63164 | 86790 | 13839 | 59 |
| 2 | 92849 | 07675 | 24187 | 42683 | 63533 | 87211 | 14323 | 58 |
| 3 | 93083 | 07936 | 24478 | 43010 | 63903 | 87633 | 14809 | 57 |
| 4 | 93318 | 08197 | 24770 | 43337 | 64274 | 88056 | 15295 | 56 |
| 5 | 93554 | 08459 | 25062 | 43666 | 64645 | 88479 | 15782 | 55 |
| 6 | 93790 | 08721 | 25355 | 43995 | 65018 | 88904 | 16271 | 54 |
| 7 | 94026 | 08983 | 25648 | 44324 | 65391 | 89330 | 16761 | 53 |
| 8 | 94263 | 09246 | 25942 | 44655 | 65765 | 89756 | 17252 | 52 |
| 9 | 94500 | 09510 | 26237 | 44986 | 66140 | 90184 | 17744 | 51 |
| 10 | 94737 | 09774 | 26531 | 45317 | 66515 | 90613 | 18238 | 50 |
| 11 | 2.94975 | 3.10038 | 3.26827 | 3.45650 | 3.66892 | 3.91042 | 4.18733 | 49 |
| 12 | 95213 | 10303 | 27123 | 45983 | 67269 | 91473 | 19228 | 48 |
| 13 | 95452 | 10568 | 27420 | 46316 | 67647 | 91904 | 19725 | 47 |
| 14 | 95691 | 10834 | 27717 | 46651 | 68025 | 92337 | 20224 | 46 |
| 15 | 95931 | 11101 | 28015 | 46986 | 68405 | 92770 | 20723 | 45 |
| 16 | 96171 | 11367 | 28313 | 47321 | 68785 | 93204 | 21224 | 44 |
| 17 | 96411 | 11635 | 28612 | 47658 | 69167 | 93640 | 21726 | 43 |
| 18 | 96652 | 11903 | 28912 | 47995 | 69549 | 94076 | 22229 | 42 |
| 19 | 96893 | 12171 | 29212 | 48333 | 69931 | 94514 | 22734 | 41 |
| 20 | 97135 | 12440 | 29512 | 48671 | 70315 | 94952 | 23239 | 40 |
| 21 | 2.97377 | 3.12709 | 3.29814 | 3.49010 | 3.70700 | 3.95392 | 4.23746 | 39 |
| 22 | 97619 | 12979 | 30115 | 49350 | 71085 | 95832 | 24255 | 38 |
| 23 | 97862 | 13249 | 30418 | 49691 | 71471 | 96274 | 24764 | 37 |
| 24 | 98106 | 13520 | 30721 | 50032 | 71858 | 96716 | 25275 | 36 |
| 25 | 98349 | 13791 | 31024 | 50374 | 72246 | 97160 | 25787 | 35 |
| 26 | 98594 | 14063 | 31328 | 50716 | 72635 | 97604 | 26300 | 34 |
| 27 | 98838 | 14335 | 31633 | 51060 | 73024 | 98050 | 26814 | 33 |
| 28 | 99083 | 14608 | 31939 | 51404 | 73414 | 98497 | 27330 | 32 |
| 29 | 99329 | 14881 | 32244 | 51748 | 73806 | 98944 | 27847 | 31 |
| 30 | 99574 | 15155 | 32551 | 52094 | 74198 | 99393 | 28366 | 30 |
| 31 | 2.99821 | 3.15429 | 3.32858 | 3.52440 | 3.74591 | 3.99843 | 4.28885 | 29 |
| 32 | 3.00067 | 15704 | 33166 | 52787 | 74984 | 4.00293 | 29406 | 28 |
| 33 | 00315 | 15979 | 33474 | 53134 | 75379 | 00745 | 29929 | 27 |
| 34 | 00562 | 16255 | 33783 | 53482 | 75775 | 01198 | 30452 | 26 |
| 35 | 00810 | 16531 | 34092 | 53831 | 76171 | 01652 | 30977 | 25 |
| 36 | 01059 | 16808 | 34403 | 54181 | 76568 | 02107 | 31503 | 24 |
| 37 | 01308 | 17085 | 34713 | 54531 | 76966 | 02563 | 32031 | 23 |
| 38 | 01557 | 17363 | 35025 | 54883 | 77365 | 03020 | 32560 | 22 |
| 39 | 01807 | 17641 | 35336 | 55235 | 77765 | 03479 | 33090 | 21 |
| 40 | 02057 | 17920 | 35649 | 55587 | 78166 | 03938 | 33622 | 20 |
| 41 | 3.02308 | 3.18199 | 3.35962 | 3.55940 | 3.78568 | 4.04398 | 4.34154 | 19 |
| 42 | 02559 | 18479 | 36276 | 56294 | 78970 | 04860 | 34689 | 18 |
| 43 | 02810 | 18759 | 36590 | 56649 | 79374 | 05322 | 35224 | 17 |
| 44 | 03062 | 19040 | 36905 | 57005 | 79778 | 05786 | 35761 | 16 |
| 45 | 03315 | 19322 | 37221 | 57361 | 80183 | 06251 | 36299 | 15 |
| 46 | 03568 | 19604 | 37537 | 57718 | 80589 | 06717 | 36839 | 14 |
| 47 | 03821 | 19886 | 37854 | 58076 | 80996 | 07184 | 37380 | 13 |
| 48 | 04075 | 20169 | 38171 | 58434 | 81404 | 07652 | 37923 | 12 |
| 49 | 04329 | 20453 | 38489 | 58794 | 81813 | 08121 | 38466 | 11 |
| 50 | 04584 | 20737 | 38808 | 59154 | 82223 | 08591 | 39012 | 10 |
| 51 | 3.04839 | 3.21021 | 3.39128 | 3.59514 | 3.82633 | 4.09063 | 4.39558 | 9 |
| 52 | 05094 | 21306 | 39448 | 59876 | 83045 | 09535 | 40106 | 8 |
| 53 | 05350 | 21592 | 39768 | 60238 | 83457 | 10009 | 40656 | 7 |
| 54 | 05607 | 21878 | 40089 | 60601 | 83871 | 10484 | 41206 | 6 |
| 55 | 05864 | 22165 | 40411 | 60965 | 84285 | 10960 | 41759 | 5 |
| 56 | 06121 | 22452 | 40734 | 61330 | 84700 | 11437 | 42312 | 4 |
| 57 | 06379 | 22740 | 41057 | 61695 | 85116 | 11915 | 42867 | 3 |
| 58 | 06637 | 23028 | 41381 | 62061 | 85533 | 12394 | 43424 | 2 |
| 59 | 06896 | 23317 | 41705 | 62428 | 85951 | 12875 | 43982 | 1 |
| 60 | 07155 | 23607 | 42030 | 62796 | 86370 | 13357 | 44541 | 0 |
| ′ | 19° | 18° | 17° | 16° | 15° | 14° | 13° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | | ′ |
|---|---|---|---|---|---|---|---|---|
| | 77° | 78° | 79° | 80° | 81° | 82° | 83° | |
| 0 | 4.44541 | 4.80973 | 5.24084 | 5.75877 | 6.39245 | 7.18530 | 8.20551 | 60 |
| 1 | 45102 | 81633 | 24870 | 76829 | 40422 | 20020 | 22500 | 59 |
| 2 | 45664 | 82294 | 25658 | 77784 | 41602 | 21517 | 24457 | 58 |
| 3 | 46228 | 82956 | 26448 | 78742 | 42787 | 23019 | 26425 | 57 |
| 4 | 46793 | 83621 | 27241 | 79703 | 43977 | 24529 | 28402 | 56 |
| 5 | 47360 | 84288 | 28036 | 80667 | 45171 | 26044 | 30388 | 55 |
| 6 | 47928 | 84956 | 28833 | 81635 | 46369 | 27566 | 32384 | 54 |
| 7 | 48498 | 85627 | 29634 | 82606 | 47572 | 29095 | 34390 | 53 |
| 8 | 49069 | 86299 | 30436 | 83581 | 48779 | 30630 | 36405 | 52 |
| 9 | 49642 | 86973 | 31241 | 84558 | 49991 | 32171 | 38431 | 51 |
| 10 | 50216 | 87649 | 32049 | 85539 | 51208 | 33719 | 40466 | 50 |
| 11 | 4.50791 | 4.88327 | 5.32859 | 5.86524 | 6.52429 | 7.35274 | 8.42511 | 49 |
| 12 | 51368 | 89007 | 33671 | 87511 | 53655 | 36835 | 44566 | 48 |
| 13 | 51947 | 89689 | 34486 | 88502 | 54886 | 38403 | 46632 | 47 |
| 14 | 52527 | 90373 | 35304 | 89497 | 56121 | 39978 | 48707 | 46 |
| 15 | 53109 | 91058 | 36124 | 90495 | 57361 | 41560 | 50793 | 45 |
| 16 | 53692 | 91746 | 36947 | 91496 | 58606 | 43148 | 52889 | 44 |
| 17 | 54277 | 92436 | 37772 | 92501 | 59855 | 44743 | 54996 | 43 |
| 18 | 54863 | 93128 | 38600 | 93509 | 61110 | 46346 | 57113 | 42 |
| 19 | 55451 | 93821 | 39430 | 94521 | 62369 | 47955 | 59241 | 41 |
| 20 | 56041 | 94517 | 40263 | 95536 | 63633 | 49571 | 61379 | 40 |
| 21 | 4.56632 | 4.95215 | 5.41099 | 5.96555 | 6.64902 | 7.51194 | 8.63528 | 39 |
| 22 | 57224 | 95914 | 41937 | 97577 | 66176 | 52825 | 65688 | 38 |
| 23 | 57819 | 96616 | 42778 | 98603 | 67454 | 54462 | 67859 | 37 |
| 24 | 58414 | 97320 | 43622 | 99633 | 68738 | 56107 | 70041 | 36 |
| 25 | 59012 | 98025 | 44468 | 6.00666 | 70027 | 57759 | 72234 | 35 |
| 26 | 59611 | 98733 | 45317 | 01703 | 71321 | 59418 | 74438 | 34 |
| 27 | 60211 | 99443 | 46169 | 02743 | 72620 | 61085 | 76653 | 33 |
| 28 | 60813 | 5.00155 | 47023 | 03787 | 73924 | 62759 | 78880 | 32 |
| 29 | 61417 | 00869 | 47881 | 04834 | 75233 | 64441 | 81118 | 31 |
| 30 | 62023 | 01585 | 48740 | 05886 | 76547 | 66130 | 83367 | 30 |
| 31 | 4.62630 | 5.02303 | 5.49603 | 6.06941 | 6.77866 | 7.67826 | 8.85628 | 29 |
| 32 | 63238 | 03024 | 50468 | 08000 | 79191 | 69530 | 87901 | 28 |
| 33 | 63849 | 03746 | 51337 | 09062 | 80521 | 71242 | 90186 | 27 |
| 34 | 64461 | 04471 | 52208 | 10129 | 81856 | 72962 | 92482 | 26 |
| 35 | 65074 | 05197 | 53081 | 11199 | 83196 | 74689 | 94791 | 25 |
| 36 | 65690 | 05926 | 53958 | 12273 | 84542 | 76424 | 97111 | 24 |
| 37 | 66307 | 06657 | 54837 | 13350 | 85893 | 78167 | 99444 | 23 |
| 38 | 66925 | 07390 | 55720 | 14432 | 87250 | 79918 | 9.01788 | 22 |
| 39 | 67545 | 08125 | 56605 | 15517 | 88612 | 81677 | 04146 | 21 |
| 40 | 68167 | 08863 | 57493 | 16607 | 89979 | 83443 | 06515 | 20 |
| 41 | 4.68791 | 5.09602 | 5.58383 | 6.17700 | 6.91352 | 7.85218 | 9.08897 | 19 |
| 42 | 69417 | 10344 | 59277 | 18797 | 92731 | 87001 | 11292 | 18 |
| 43 | 70044 | 11088 | 60174 | 19898 | 94115 | 88792 | 13699 | 17 |
| 44 | 70673 | 11835 | 61073 | 21004 | 95505 | 90592 | 16120 | 16 |
| 45 | 71303 | 12583 | 61976 | 22113 | 96900 | 92400 | 18553 | 15 |
| 46 | 71935 | 13334 | 62881 | 23226 | 98301 | 94216 | 20999 | 14 |
| 47 | 72569 | 14087 | 63790 | 24343 | 99708 | 96040 | 23459 | 13 |
| 48 | 73205 | 14842 | 64701 | 25464 | 7.01120 | 97873 | 25931 | 12 |
| 49 | 73843 | 15599 | 65616 | 26590 | 02538 | 99714 | 28417 | 11 |
| 50 | 74482 | 16359 | 66533 | 27719 | 03962 | 8.01565 | 30917 | 10 |
| 51 | 4.75123 | 5.17121 | 5.67454 | 6.28853 | 7.05392 | 8.03423 | 9.33430 | 9 |
| 52 | 75766 | 17886 | 68377 | 29991 | 06828 | 05291 | 35957 | 8 |
| 53 | 76411 | 18652 | 69304 | 31133 | 08269 | 07167 | 38497 | 7 |
| 54 | 77057 | 19421 | 70234 | 32279 | 09717 | 09052 | 41052 | 6 |
| 55 | 77705 | 20193 | 71166 | 33429 | 11171 | 10946 | 43620 | 5 |
| 56 | 78355 | 20966 | 72102 | 34584 | 12630 | 12849 | 46203 | 4 |
| 57 | 79007 | 21742 | 73041 | 35743 | 14096 | 14760 | 48800 | 3 |
| 58 | 79661 | 22521 | 73983 | 36906 | 15568 | 16681 | 51411 | 2 |
| 59 | 80316 | 23301 | 74929 | 38073 | 17046 | 18612 | 54037 | 1 |
| 60 | 80973 | 24084 | 75877 | 39245 | 18530 | 20551 | 56677 | 0 |
| ′ | 12° | 11° | 10° | 9° | 8° | 7° | 6° | ′ |
| | COSECANTS. | | | | | | | |

| ′ | SECANTS. | | | | | | ′ |
|---|---|---|---|---|---|---|---|
| | 84° | 85° | 86° | 87° | 88° | 89° | |
| 0 | 9.56677 | 11.47371 | 14.33559 | 19.10732 | 28.65371 | 57.29869 | 60 |
| 1 | 59332 | 51199 | 39547 | 21397 | 89440 | 58.26976 | 59 |
| 2 | 62002 | 55052 | 45586 | 32182 | 29.13917 | 59.27431 | 58 |
| 3 | 64687 | 58932 | 51676 | 43088 | 38812 | 60.31411 | 57 |
| 4 | 67387 | 62837 | 57817 | 54119 | 64137 | 61.39105 | 56 |
| 5 | 70103 | 66769 | 64011 | 65275 | 89903 | 62.50715 | 55 |
| 6 | 72833 | 70728 | 70258 | 76560 | 30.16120 | 63.66460 | 54 |
| 7 | 75579 | 74714 | 76558 | 87976 | 42802 | 64.86572 | 53 |
| 8 | 78341 | 78727 | 82913 | 99524 | 69960 | 66.11304 | 52 |
| 9 | 81119 | 82768 | 89323 | 20.11208 | 97607 | 67.40927 | 51 |
| 10 | 83912 | 86837 | 95788 | 23028 | 31.25758 | 68.75736 | 50 |
| 11 | 9.86722 | 11.90934 | 15.02310 | 20.34989 | 31.54425 | 70.16047 | 49 |
| 12 | 89547 | 95060 | 08890 | 47093 | 83623 | 71.62207 | 48 |
| 13 | 92389 | 99214 | 15527 | 59341 | 32.13366 | 73.14583 | 47 |
| 14 | 95248 | 12.03397 | 22223 | 71737 | 43671 | 74.73586 | 46 |
| 15 | 98123 | 07610 | 28979 | 84283 | 74554 | 76.39655 | 45 |
| 16 | 10.01015 | 11852 | 35795 | 96982 | 33.06030 | 78.13274 | 44 |
| 17 | 03923 | 16125 | 42672 | 21.09838 | 38118 | 79.94968 | 43 |
| 18 | 06849 | 20427 | 49611 | 22852 | 70835 | 81.85315 | 42 |
| 19 | 09792 | 24761 | 56614 | 36027 | 34.04199 | 83.84947 | 41 |
| 20 | 12752 | 29125 | 63679 | 49368 | 38232 | 85.94561 | 40 |
| 21 | 10.15730 | 12.33521 | 15.70810 | 21.62876 | 34.72952 | 88.14924 | 39 |
| 22 | 18725 | 37948 | 78005 | 76555 | 35.08380 | 90.46886 | 38 |
| 23 | 21739 | 42408 | 85268 | 90409 | 44539 | 92.91387 | 37 |
| 24 | 24770 | 46900 | 92597 | 22.04440 | 81452 | 95.49471 | 36 |
| 25 | 27819 | 51424 | 99995 | 18653 | 36.19141 | 98.22303 | 35 |
| 26 | 30887 | 55982 | 16.07462 | 33050 | 57633 | 101.11185 | 34 |
| 27 | 33973 | 60572 | 14999 | 47635 | 96953 | 104.17574 | 33 |
| 28 | 37077 | 65197 | 22607 | 62413 | 37.37127 | 107.43114 | 32 |
| 29 | 40201 | 69856 | 30287 | 77386 | 78185 | 110.89656 | 31 |
| 30 | 43343 | 74550 | 38041 | 92559 | 38.20155 | 114.59301 | 30 |
| 31 | 10.46505 | 12.79278 | 16.45869 | 23.07935 | 38.63068 | 118.54440 | 29 |
| 32 | 49685 | 84042 | 53772 | 23520 | 39.06957 | 122.77803 | 28 |
| 33 | 52886 | 88841 | 61751 | 39316 | 51855 | 127.32526 | 27 |
| 34 | 56106 | 93677 | 69808 | 55329 | 97797 | 132.22229 | 26 |
| 35 | 59346 | 98549 | 77944 | 71563 | 40.44820 | 137.51108 | 25 |
| 36 | 62605 | 13.03458 | 86159 | 88022 | 92963 | 143.24061 | 24 |
| 37 | 65885 | 08404 | 94456 | 24.04712 | 41.42266 | 149.46837 | 23 |
| 38 | 69186 | 13388 | 17.02835 | 21637 | 92772 | 156.26228 | 22 |
| 39 | 72507 | 18411 | 11297 | 38802 | 42.44525 | 163.70325 | 21 |
| 40 | 75849 | 23472 | 19843 | 56212 | 97571 | 171.88831 | 20 |
| 41 | 10.79212 | 13.28572 | 17.28476 | 24.73873 | 43.51961 | 180.93496 | 19 |
| 42 | 82596 | 33712 | 37196 | 91790 | 44.07746 | 190.98680 | 18 |
| 43 | 86001 | 38891 | 46005 | 25.09969 | 64980 | 202.22122 | 17 |
| 44 | 89428 | 44112 | 54903 | 28414 | 45.23720 | 214.85995 | 16 |
| 45 | 92877 | 49373 | 63893 | 47134 | 84026 | 229.18385 | 15 |
| 46 | 96348 | 54676 | 72975 | 66132 | 46.45963 | 245.55402 | 14 |
| 47 | 99841 | 60021 | 82152 | 85417 | 47.09596 | 264.44269 | 13 |
| 48 | 11.03356 | 65408 | 91424 | 26.04994 | 74997 | 286.47948 | 12 |
| 49 | 06894 | 70838 | 18.00794 | 24869 | 48.42241 | 312.52297 | 11 |
| 50 | 10455 | 76312 | 10262 | 45051 | 49.11406 | 343.77516 | 10 |
| 51 | 11.14039 | 13.81829 | 18.19830 | 26.65546 | 49.82576 | 381.97230 | 9 |
| 52 | 17646 | 87391 | 29501 | 86360 | 50.55840 | 429.71873 | 8 |
| 53 | 21277 | 92999 | 39274 | 27.07503 | 51.31290 | 491.10702 | 7 |
| 54 | 24932 | 98651 | 49153 | 28981 | 52.09027 | 572.95809 | 6 |
| 55 | 28610 | 14.04350 | 59139 | 50804 | 89156 | 687.54960 | 5 |
| 56 | 32313 | 10096 | 69233 | 72978 | 53.71790 | 859.43689 | 4 |
| 57 | 36040 | 15889 | 79438 | 95513 | 54.57046 | 1145.9157 | 3 |
| 58 | 39792 | 21730 | 89755 | 28.18417 | 55.45053 | 1718.8735 | 2 |
| 59 | 43569 | 27620 | 19.00185 | 41700 | 56.35946 | 3437.7468 | 1 |
| 60 | 47371 | 33559 | 10732 | 65371 | 57.29869 | ∞ | 0 |
| ′ | 5° | 4° | 3° | 2° | 1° | 0° | ′ |
| | COSECANTS. | | | | | | |

| ′ | 0° | | 1° | | 2° | | 3° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .00000 | Infinite. | .01746 | 57.2900 | .03492 | 28.6363 | .05241 | 19.0811 | 60 |
| 1 | .00029 | 3437.75 | .01775 | 56.3506 | .03521 | 28.3994 | .05270 | 18.9755 | 59 |
| 2 | .00058 | 1718.87 | .01804 | 55.4415 | .03550 | 28.1664 | .05299 | 18.8711 | 58 |
| 3 | .00087 | 1145.92 | .01833 | 54.5613 | .03579 | 27.9372 | .05328 | 18.7678 | 57 |
| 4 | .00116 | 859.436 | .01862 | 53.7086 | .03609 | 27.7117 | .05357 | 18.6656 | 56 |
| 5 | .00145 | 687.549 | .01891 | 52.8821 | .03638 | 27.4899 | .05387 | 18.5645 | 55 |
| 6 | .00175 | 572.957 | .01920 | 52.0807 | .03667 | 27.2715 | .05416 | 18.4645 | 54 |
| 7 | .00204 | 491.106 | .01949 | 51.3032 | .03696 | 27.0566 | .05445 | 18.3655 | 53 |
| 8 | .00233 | 429.718 | .01978 | 50.5485 | .03725 | 26.8450 | .05474 | 18.2677 | 52 |
| 9 | .00262 | 381.971 | .02007 | 49.8157 | .03754 | 26.6367 | .05503 | 18.1708 | 51 |
| 10 | .00291 | 343.774 | .02036 | 49.1039 | .03783 | 26.4316 | .05533 | 18.0750 | 50 |
| 11 | .00320 | 312.521 | .02066 | 48.4121 | .03812 | 26.2296 | .05562 | 17.9802 | 49 |
| 12 | .00349 | 286.478 | .02095 | 47.7395 | .03842 | 26.0307 | .05591 | 17.8863 | 48 |
| 13 | .00378 | 264.441 | .02124 | 47.0853 | .03871 | 25.8348 | .05620 | 17.7934 | 47 |
| 14 | .00407 | 245.552 | .02153 | 46.4489 | .03900 | 25.6418 | .05649 | 17.7015 | 46 |
| 15 | .00436 | 229.182 | .02182 | 45.8294 | .03929 | 25.4517 | .05678 | 17.6106 | 45 |
| 16 | .00465 | 214.858 | .02211 | 45.2261 | .03958 | 25.2644 | .05708 | 17.5205 | 44 |
| 17 | .00495 | 202.219 | .02240 | 44.6386 | .03987 | 25.0798 | .05737 | 17.4314 | 43 |
| 18 | .00524 | 190.984 | .02269 | 44.0661 | .04016 | 24.8978 | .05766 | 17.3432 | 42 |
| 19 | .00553 | 180.932 | .02298 | 43.5081 | .04046 | 24.7185 | .05795 | 17.2558 | 41 |
| 20 | .00582 | 171.885 | .02328 | 42.9641 | .04075 | 24.5418 | .05824 | 17.1693 | 40 |
| 21 | .00611 | 163.700 | .02357 | 42.4335 | .04104 | 24.3675 | .05854 | 17.0837 | 39 |
| 22 | .00640 | 156.259 | .02386 | 41.9158 | .04133 | 24.1957 | .05883 | 16.9990 | 38 |
| 23 | .00669 | 149.465 | .02415 | 41.4106 | .04162 | 24.0263 | .05912 | 16.9150 | 37 |
| 24 | .00698 | 143.237 | .02444 | 40.9174 | .04191 | 23.8593 | .05941 | 16.8319 | 36 |
| 25 | .00727 | 137.507 | .02473 | 40.4358 | .04220 | 23.6945 | .05970 | 16.7496 | 35 |
| 26 | .00756 | 132.219 | .02502 | 39.9655 | .04250 | 23.5321 | .05999 | 16.6681 | 34 |
| 27 | .00785 | 127.321 | .02531 | 39.5059 | .04279 | 23.3718 | .06029 | 16.5874 | 33 |
| 28 | .00815 | 122.774 | .02560 | 39.0568 | .04308 | 23.2137 | .06058 | 16.5075 | 32 |
| 29 | .00844 | 118.540 | .02589 | 38.6177 | .04337 | 23.0577 | .06087 | 16.4283 | 31 |
| 30 | .00873 | 114.589 | .02619 | 38.1885 | .04366 | 22.9038 | .06116 | 16.3499 | 30 |
| 31 | .00902 | 110.892 | .02648 | 37.7686 | .04395 | 22.7519 | .06145 | 16.2722 | 29 |
| 32 | .00931 | 107.426 | .02677 | 37.3579 | .04424 | 22.6020 | .06175 | 16.1952 | 28 |
| 33 | .00960 | 104.171 | .02706 | 36.9560 | .04454 | 22.4541 | .06204 | 16.1190 | 27 |
| 34 | .00989 | 101.107 | .02735 | 36.5627 | .04483 | 22.3081 | .06233 | 16.0435 | 26 |
| 35 | .01018 | 98.2179 | .02764 | 36.1776 | .04512 | 22.1640 | .06262 | 15.9687 | 25 |
| 36 | .01047 | 95.4895 | .02793 | 35.8006 | .04541 | 22.0217 | .06291 | 15.8945 | 24 |
| 37 | .01076 | 92.9085 | .02822 | 35.4313 | .04570 | 21.8813 | .06321 | 15.8211 | 23 |
| 38 | .01105 | 90.4633 | .02851 | 35.0695 | .04599 | 21.7426 | .06350 | 15.7483 | 22 |
| 39 | .01135 | 88.1436 | .02881 | 34.7151 | .04628 | 21.6056 | .06379 | 15.6762 | 21 |
| 40 | .01164 | 85.9398 | .02910 | 34.3678 | .04658 | 21.4704 | .06408 | 15.6048 | 20 |
| 41 | .01193 | 83.8435 | .02939 | 34.0273 | .04687 | 21.3369 | .06437 | 15.5340 | 19 |
| 42 | .01222 | 81.8470 | .02968 | 33.6935 | .04716 | 21.2049 | .06467 | 15.4638 | 18 |
| 43 | .01251 | 79.9434 | .02997 | 33.3662 | .04745 | 21.0747 | .06496 | 15.3943 | 17 |
| 44 | .01280 | 78.1263 | .03026 | 33.0452 | .04774 | 20.9460 | .06525 | 15.3254 | 16 |
| 45 | .01309 | 76.3900 | .03055 | 32.7303 | .04803 | 20.8188 | .06554 | 15.2571 | 15 |
| 46 | .01338 | 74.7292 | .03084 | 32.4213 | .04833 | 20.6932 | .06584 | 15.1893 | 14 |
| 47 | .01367 | 73.1390 | .03114 | 32.1181 | .04862 | 20.5691 | .06613 | 15.1222 | 13 |
| 48 | .01396 | 71.6151 | .03143 | 31.8205 | .04891 | 20.4465 | .06642 | 15.0557 | 12 |
| 49 | .01425 | 70.1533 | .03172 | 31.5284 | .04920 | 20.3253 | .06671 | 14.9898 | 11 |
| 50 | .01455 | 68.7501 | .03201 | 31.2416 | .04949 | 20.2056 | .06700 | 14.9244 | 10 |
| 51 | .01484 | 67.4019 | .03230 | 30.9599 | .04978 | 20.0872 | .06730 | 14.8596 | 9 |
| 52 | .01513 | 66.1055 | .03259 | 30.6833 | .05007 | 19.9702 | .06759 | 14.7954 | 8 |
| 53 | .01542 | 64.8580 | .03288 | 30.4116 | .05037 | 19.8546 | .06788 | 14.7317 | 7 |
| 54 | .01571 | 63.6567 | .03317 | 30.1446 | .05066 | 19.7403 | .06817 | 14.6685 | 6 |
| 55 | .01600 | 62.4992 | .03346 | 29.8823 | .05095 | 19.6273 | .06847 | 14.6059 | 5 |
| 56 | .01629 | 61.3829 | .03376 | 29.6245 | .05124 | 19.5156 | .06876 | 14.5438 | 4 |
| 57 | .01658 | 60.3058 | .03405 | 29.3711 | .05153 | 19.4051 | .06905 | 14.4823 | 3 |
| 58 | .01687 | 59.2659 | .03434 | 29.1220 | .05182 | 19.2959 | .06934 | 14.4212 | 2 |
| 59 | .01716 | 58.2612 | .03463 | 28.8771 | .05212 | 19.1879 | .06963 | 14.3607 | 1 |
| 60 | .01746 | 57.2900 | .03492 | 28.6363 | .05241 | 19.0811 | .06993 | 14.3007 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 89° | | 88° | | 87° | | 86° | | |

| ′ | 4° | | 5° | | 6° | | 7° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .06993 | 14.3007 | .08749 | 11.4301 | .10510 | 9.51436 | .12278 | 8.14435 | 60 |
| 1 | .07022 | 14.2411 | .08778 | 11.3919 | .10540 | 9.48781 | .12308 | 8.12481 | 59 |
| 2 | .07051 | 14.1821 | .08807 | 11.3540 | .10569 | 9.46141 | .12338 | 8.10536 | 58 |
| 3 | .07080 | 14.1235 | .08837 | 11.3163 | .10599 | 9.43515 | .12367 | 8.08600 | 57 |
| 4 | .07110 | 14.0655 | .08866 | 11.2789 | .10628 | 9.40904 | .12397 | 8.06674 | 56 |
| 5 | .07139 | 14.0079 | .08895 | 11.2417 | .10657 | 9.38307 | .12426 | 8.04756 | 55 |
| 6 | .07168 | 13.9507 | .08925 | 11.2048 | .10687 | 9.35724 | .12456 | 8.02848 | 54 |
| 7 | .07197 | 13.8940 | .08954 | 11.1681 | .10716 | 9.33155 | .12485 | 8.00948 | 53 |
| 8 | .07227 | 13.8378 | .08983 | 11.1316 | .10746 | 9.30599 | .12515 | 7.99058 | 52 |
| 9 | .07256 | 13.7821 | .09013 | 11.0954 | .10775 | 9.28058 | .12544 | 7.97176 | 51 |
| 10 | .07285 | 13.7267 | .09042 | 11.0594 | .10805 | 9.25530 | .12574 | 7.95302 | 50 |
| 11 | .07314 | 13.6719 | .09071 | 11.0237 | .10834 | 9.23016 | .12603 | 7.93438 | 49 |
| 12 | .07344 | 13.6174 | .09101 | 10.9882 | .10863 | 9.20516 | .12633 | 7.91582 | 48 |
| 13 | .07373 | 13.5634 | .09130 | 10.9529 | .10893 | 9.18028 | .12662 | 7.89734 | 47 |
| 14 | .07402 | 13.5098 | .09159 | 10.9178 | .10922 | 9.15554 | .12692 | 7.87895 | 46 |
| 15 | .07431 | 13.4566 | .09189 | 10.8829 | .10952 | 9.13093 | .12722 | 7.86064 | 45 |
| 16 | .07461 | 13.4039 | .09218 | 10.8483 | .10981 | 9.10646 | .12751 | 7.84242 | 44 |
| 17 | .07490 | 13.3515 | .09247 | 10.8139 | .11011 | 9.08211 | .12781 | 7.82428 | 43 |
| 18 | .07519 | 13.2996 | .09277 | 10.7797 | .11040 | 9.05789 | .12810 | 7.80622 | 42 |
| 19 | .07548 | 13.2480 | .09306 | 10.7457 | .11070 | 9.03379 | .12840 | 7.78825 | 41 |
| 20 | .07578 | 13.1969 | .09335 | 10.7119 | .11099 | 9.00983 | .12869 | 7.77035 | 40 |
| 21 | .07607 | 13.1461 | .09365 | 10.6783 | .11128 | 8.98598 | .12899 | 7.75254 | 39 |
| 22 | .07636 | 13.0958 | .09394 | 10.6450 | .11158 | 8.96227 | .12929 | 7.73480 | 38 |
| 23 | .07665 | 13.0458 | .09423 | 10.6118 | .11187 | 8.93867 | .12958 | 7.71715 | 37 |
| 24 | .07695 | 12.9962 | .09453 | 10.5789 | .11217 | 8.91520 | .12988 | 7.69957 | 36 |
| 25 | .07724 | 12.9469 | .09482 | 10.5462 | .11246 | 8.89185 | .13017 | 7.68208 | 35 |
| 26 | .07753 | 12.8981 | .09511 | 10.5136 | .11276 | 8.86862 | .13047 | 7.66466 | 34 |
| 27 | .07782 | 12.8496 | .09541 | 10.4813 | .11305 | 8.84551 | .13076 | 7.64732 | 33 |
| 28 | .07812 | 12.8014 | .09570 | 10.4491 | .11335 | 8.82252 | .13106 | 7.63005 | 32 |
| 29 | .07841 | 12.7536 | .09600 | 10.4172 | .11364 | 8.79964 | .13136 | 7.61287 | 31 |
| 30 | .07870 | 12.7062 | .09629 | 10.3854 | .11394 | 8.77689 | .13165 | 7.59575 | 30 |
| 31 | .07899 | 12.6591 | .09658 | 10.3538 | .11423 | 8.75425 | .13195 | 7.57872 | 29 |
| 32 | .07929 | 12.6124 | .09688 | 10.3224 | .11452 | 8.73172 | .13224 | 7.56176 | 28 |
| 33 | .07958 | 12.5660 | .09717 | 10.2913 | .11482 | 8.70931 | .13254 | 7.54487 | 27 |
| 34 | .07987 | 12.5199 | .09746 | 10.2602 | .11511 | 8.68701 | .13284 | 7.52806 | 26 |
| 35 | .08017 | 12.4742 | .09776 | 10.2294 | .11541 | 8.66482 | .13313 | 7.51132 | 25 |
| 36 | .08046 | 12.4288 | .09805 | 10.1988 | .11570 | 8.64275 | .13343 | 7.49465 | 24 |
| 37 | .08075 | 12.3838 | .09834 | 10.1683 | .11600 | 8.62078 | .13372 | 7.47806 | 23 |
| 38 | .08104 | 12.3390 | .09864 | 10.1381 | .11629 | 8.59893 | .13402 | 7.46154 | 22 |
| 39 | .08134 | 12.2946 | .09893 | 10.1080 | .11659 | 8.57718 | .13432 | 7.44509 | 21 |
| 40 | .08163 | 12.2505 | .09923 | 10.0780 | .11688 | 8.55555 | .13461 | 7.42871 | 20 |
| 41 | .08192 | 12.2067 | .09952 | 10.0483 | .11718 | 8.53402 | .13491 | 7.41240 | 19 |
| 42 | .08221 | 12.1632 | .09981 | 10.0187 | .11747 | 8.51259 | .13521 | 7.39616 | 18 |
| 43 | .08251 | 12.1201 | .10011 | 9.98931 | .11777 | 8.49128 | .13550 | 7.37999 | 17 |
| 44 | .08280 | 12.0772 | .10040 | 9.96007 | .11806 | 8.47007 | .13580 | 7.36389 | 16 |
| 45 | .08309 | 12.0346 | .10069 | 9.93101 | .11836 | 8.44896 | .13609 | 7.34786 | 15 |
| 46 | .08339 | 11.9923 | .10099 | 9.90211 | .11865 | 8.42795 | .13639 | 7.33190 | 14 |
| 47 | .08368 | 11.9504 | .10128 | 9.87338 | .11895 | 8.40705 | .13669 | 7.31600 | 13 |
| 48 | .08397 | 11.9087 | .10158 | 9.84482 | .11924 | 8.38625 | .13698 | 7.30018 | 12 |
| 49 | .08427 | 11.8673 | .10187 | 9.81641 | .11954 | 8.36555 | .13728 | 7.28442 | 11 |
| 50 | .08456 | 11.8262 | .10216 | 9.78817 | .11983 | 8.34496 | .13758 | 7.26873 | 10 |
| 51 | .08485 | 11.7853 | .10246 | 8.76009 | .12013 | 8.32446 | .13787 | 7.25310 | 9 |
| 52 | .08514 | 11.7448 | .10275 | 9.73217 | .12042 | 8.30406 | .13817 | 7.23754 | 8 |
| 53 | .08544 | 11.7045 | .10305 | 9.70441 | .12072 | 8.28376 | .13846 | 7.22204 | 7 |
| 54 | .08573 | 11.6645 | .10334 | 9.67680 | .12101 | 8.26355 | .13876 | 7.20661 | 6 |
| 55 | .08602 | 11.6248 | .10363 | 9.64935 | .12131 | 8.24345 | .13906 | 7.19125 | 5 |
| 56 | .08632 | 11.5853 | .10393 | 9.62205 | .12160 | 8.22344 | .13935 | 7.17594 | 4 |
| 57 | .08661 | 11.5461 | .10422 | 9.59490 | .12190 | 8.20352 | .13965 | 7.16071 | 3 |
| 58 | .08690 | 11 5072 | .10452 | 9.56791 | .12219 | 8.18370 | .13995 | 7.14553 | 2 |
| 59 | .08720 | 11.4685 | .10481 | 9.54106 | .12249 | 8.16398 | .14024 | 7.13042 | 1 |
| 60 | .08749 | 11.4301 | .10510 | 9.51436 | .12278 | 8.14435 | .14054 | 7.11537 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 85° | | 84° | | 83° | | 82° | | |

| ′ | 8° |  | 9° |  | 10° |  | 11° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang |  |
| 0 | .14054 | 7.11537 | .15838 | 6.31375 | .17633 | 5.67128 | .19438 | 5.14455 | 60 |
| 1 | .14084 | 7.10038 | .15868 | 6.30189 | .17663 | 5.66165 | .19468 | 5.13658 | 59 |
| 2 | .14113 | 7.08546 | .15898 | 6.29007 | .17693 | 5.65205 | .19498 | 5.12862 | 58 |
| 3 | .14143 | 7.07059 | .15928 | 6.27829 | .17723 | 5.64248 | .19529 | 5.12069 | 57 |
| 4 | .14173 | 7.05579 | .15958 | 6.26655 | .17753 | 5.63295 | .19559 | 5.11279 | 56 |
| 5 | .14202 | 7.04105 | .15988 | 6.25486 | .17783 | 5.62344 | .19589 | 5.10490 | 55 |
| 6 | .14232 | 7.02637 | .16017 | 6.24321 | .17813 | 5.61397 | .19619 | 5.09704 | 54 |
| 7 | .14262 | 7.01174 | .16047 | 6.23160 | .17843 | 5.60452 | .19649 | 5.08921 | 53 |
| 8 | .14291 | 6.99718 | .16077 | 6.22003 | .17873 | 5.59511 | .19680 | 5.08139 | 52 |
| 9 | .14321 | 6.98268 | .16107 | 6.20851 | .17903 | 5.58573 | .19710 | 5.07360 | 51 |
| 10 | .14351 | 6.96823 | .16137 | 6.19703 | .17933 | 5.57638 | .19740 | 5.06584 | 50 |
| 11 | .14381 | 6.95385 | .16167 | 6.18559 | .17963 | 5.56706 | .19770 | 5.05809 | 49 |
| 12 | .14410 | 6.93952 | .16196 | 6.17419 | .17993 | 5.55777 | .19801 | 5.05037 | 48 |
| 13 | .14440 | 6.92525 | .16226 | 6.16283 | .18023 | 5.54851 | .19831 | 5.04267 | 47 |
| 14 | .14470 | 6.91104 | .16256 | 6.15151 | .18053 | 5.53927 | .19861 | 5.03499 | 46 |
| 15 | .14499 | 6.89688 | .16286 | 6.14023 | .18083 | 5.53007 | .19891 | 5.02734 | 45 |
| 16 | .14529 | 6.88278 | .16316 | 6.12899 | .18113 | 5.52090 | .19921 | 5.01971 | 44 |
| 17 | .14559 | 6.86874 | .16346 | 6.11779 | .18143 | 5.51176 | .19952 | 5.01210 | 43 |
| 18 | .14588 | 6.85475 | .16376 | 6.10664 | .18173 | 5.50264 | .19982 | 5.00451 | 42 |
| 19 | .14618 | 6.84082 | .16405 | 6.09552 | .18203 | 5.49356 | .20012 | 4.99695 | 41 |
| 20 | .14648 | 6.82694 | .16435 | 6.08444 | .18233 | 5.48451 | .20042 | 4.98940 | 40 |
| 21 | .14678 | 6.81312 | .16465 | 6.07340 | .18263 | 5.47548 | .20073 | 4.98188 | 39 |
| 22 | .14707 | 6.79936 | .16495 | 6.06240 | .18293 | 5.46648 | .20103 | 4.97438 | 38 |
| 23 | .14737 | 6.78564 | .16525 | 6.05143 | .18323 | 5.45751 | .20133 | 4.96690 | 37 |
| 24 | .14767 | 6.77199 | .16555 | 6.04051 | .18353 | 5.44857 | .20164 | 4.95945 | 36 |
| 25 | .14796 | 6.75838 | .16585 | 6.02962 | .18384 | 5.43966 | .20194 | 4.95201 | 35 |
| 26 | .14826 | 6.74483 | .16615 | 6.01878 | .18414 | 5.43077 | .20224 | 4.94460 | 34 |
| 27 | .14856 | 6.73133 | .16645 | 6.00797 | .18444 | 5.42192 | .20254 | 4.93721 | 33 |
| 28 | .14886 | 6.71789 | .16674 | 5.99720 | .18474 | 5.41309 | .20285 | 4.92984 | 32 |
| 29 | .14915 | 6.70450 | .16704 | 5.98646 | .18504 | 5.40429 | .20315 | 4.92249 | 31 |
| 30 | .14945 | 6.69116 | .16734 | 5.97576 | .18534 | 5.39552 | .20345 | 4.91516 | 30 |
| 31 | .14975 | 6.67787 | .16764 | 5.96510 | .18564 | 5.38677 | .20376 | 4.90785 | 29 |
| 32 | .15005 | 6.66463 | .16794 | 5.95448 | .18594 | 5.37805 | .20406 | 4.90056 | 28 |
| 33 | .15034 | 6.65144 | .16824 | 5.94390 | .18624 | 5.36936 | .20436 | 4.89330 | 27 |
| 34 | .15064 | 6.63831 | .16854 | 5.93335 | .18654 | 5.36070 | .20466 | 4.88605 | 26 |
| 35 | .15094 | 6.62523 | .16884 | 5.92283 | .18684 | 5.35206 | .20497 | 4.87882 | 25 |
| 36 | .15124 | 6.61219 | .16914 | 5.91236 | .18714 | 5.34345 | .20527 | 4.87162 | 24 |
| 37 | .15153 | 6.59921 | .16944 | 5.90191 | .18745 | 5.33487 | .20557 | 4.86444 | 23 |
| 38 | .15183 | 6.58627 | .16974 | 5.89151 | .18775 | 5.32631 | .20588 | 4.85727 | 22 |
| 39 | .15213 | 6.57339 | .17004 | 5.88114 | .18805 | 5.31778 | .20618 | 4.85013 | 21 |
| 40 | .15243 | 6.56055 | .17033 | 5.87080 | .18835 | 5.30928 | .20648 | 4.84300 | 20 |
| 41 | .15272 | 6.54777 | .17063 | 5.86051 | .18865 | 5.30080 | .20679 | 4.83590 | 19 |
| 42 | .15302 | 6.53503 | .17093 | 5.85024 | .18895 | 5.29235 | .20709 | 4.82882 | 18 |
| 43 | .15332 | 6.52234 | .17123 | 5.84001 | .18925 | 5.28393 | .20739 | 4.82175 | 17 |
| 44 | .15362 | 6.50970 | .17153 | 5.82982 | .18955 | 5.27553 | .20770 | 4.81471 | 16 |
| 45 | .15391 | 6.49710 | .17183 | 5.81966 | .18986 | 5.26715 | .20800 | 4.80769 | 15 |
| 46 | .15421 | 6.48456 | .17213 | 5.80953 | .19016 | 5.25880 | .20830 | 4.80068 | 14 |
| 47 | .15451 | 6.47206 | .17243 | 5.79944 | .19046 | 5.25048 | .20861 | 4.79370 | 13 |
| 48 | .15481 | 6.45961 | .17273 | 5.78938 | .19076 | 5.24218 | .20891 | 4.78673 | 12 |
| 49 | .15511 | 6.44720 | .17303 | 5.77936 | .19106 | 5.23391 | .20921 | 4.77978 | 11 |
| 50 | .15540 | 6.43484 | .17333 | 5.76937 | .19136 | 5.22566 | .20952 | 4.77286 | 10 |
| 51 | .15570 | 6.42253 | .17363 | 5.75941 | .19166 | 5.21744 | .20982 | 4.76595 | 9 |
| 52 | .15600 | 6.41026 | .17393 | 5.74949 | .19197 | 5.20925 | .21013 | 4.75906 | 8 |
| 53 | .15630 | 6.39804 | .17423 | 5.73960 | .19227 | 5.20107 | .21043 | 4.75219 | 7 |
| 54 | .15660 | 6.38587 | .17453 | 5.72974 | .19257 | 5.19293 | .21073 | 4.74534 | 6 |
| 55 | .15689 | 6.37374 | .17483 | 5.71992 | .19287 | 5.18480 | .21104 | 4.73851 | 5 |
| 56 | .15719 | 6.36165 | .17513 | 5.71013 | .19317 | 5.17671 | .21134 | 4.73170 | 4 |
| 57 | .15749 | 6.34961 | .17543 | 5.70037 | .19347 | 5.16863 | .21164 | 4.72490 | 3 |
| 58 | .15779 | 6.33761 | .17573 | 5.69064 | .19378 | 5.16058 | .21195 | 4.71813 | 2 |
| 59 | .15809 | 6.32566 | .17603 | 5.68094 | .19408 | 5.15256 | .21225 | 4.71137 | 1 |
| 60 | .15838 | 6.31375 | .17633 | 5.67128 | .19438 | 5.14455 | .21256 | 4.70463 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
|  | 81° |  | 80° |  | 79° |  | 78° |  |  |

| ′ | 12° | | 13° | | 14° | | 15° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .21256 | 4.70463 | .23087 | 4.33148 | .24933 | 4.01078 | .26795 | 3.73205 | 60 |
| 1 | .21286 | 4.69791 | .23117 | 4.32573 | .24964 | 4.00582 | .26826 | 3.72771 | 59 |
| 2 | .21316 | 4.69121 | .23148 | 4.32001 | .24995 | 4.00086 | .26857 | 3.72338 | 58 |
| 3 | .21347 | 4.68452 | .23179 | 4.31430 | .25026 | 3.99592 | .26888 | 3.71907 | 57 |
| 4 | .21377 | 4.67786 | .23209 | 4.30860 | .25056 | 3.99099 | .26920 | 3.71476 | 56 |
| 5 | .21408 | 4.67121 | .23240 | 4.30291 | .25087 | 3.98607 | .26951 | 3.71046 | 55 |
| 6 | .21438 | 4.66458 | .23271 | 4.29724 | .25118 | 3.98117 | .26982 | 3.70616 | 54 |
| 7 | .21469 | 4.65797 | .23301 | 4.29159 | .25149 | 3.97627 | .27013 | 3.70188 | 53 |
| 8 | .21499 | 4.65138 | .23332 | 4.28595 | .25180 | 3.97139 | .27044 | 3.69761 | 52 |
| 9 | .21529 | 4.64480 | .23363 | 4.28032 | .25211 | 3.96651 | .27076 | 3.69335 | 51 |
| 10 | .21560 | 4.63825 | .23393 | 4.27471 | .25242 | 3.96165 | .27107 | 3.68909 | 50 |
| 11 | .21590 | 4.63171 | .23424 | 4.26911 | .25273 | 3.95680 | .27138 | 3.68485 | 49 |
| 12 | .21621 | 4.62518 | .23455 | 4.26352 | .25304 | 3.95196 | .27169 | 3.68061 | 48 |
| 13 | .21651 | 4.61868 | .23485 | 4.25795 | .25335 | 3.94713 | .27201 | 3.67638 | 47 |
| 14 | .21682 | 4.61219 | .23516 | 4.25239 | .25366 | 3.94232 | .27232 | 3.67217 | 46 |
| 15 | .21712 | 4.60572 | .23547 | 4.24685 | .25397 | 3.93751 | .27263 | 3.66796 | 45 |
| 16 | .21743 | 4.59927 | .23578 | 4.24132 | .25428 | 3.93271 | .27294 | 3.66376 | 44 |
| 17 | .21773 | 4.59283 | .23608 | 4.23580 | .25459 | 3.92793 | .27326 | 3.65957 | 43 |
| 18 | .21804 | 4.58641 | .23639 | 4.23030 | .25490 | 3.92316 | .27357 | 3.65538 | 42 |
| 19 | .21834 | 4.58001 | .23670 | 4.22481 | .25521 | 3.91839 | .27388 | 3.65121 | 41 |
| 20 | .21864 | 4.57363 | .23700 | 4.21933 | .25552 | 3.91364 | .27419 | 3.64705 | 40 |
| 21 | .21895 | 4.56726 | .23731 | 4.21387 | .25583 | 3.90890 | .27451 | 3.64289 | 39 |
| 22 | .21925 | 4.56091 | .23762 | 4.20342 | .25614 | 3.90417 | .27482 | 3.63874 | 38 |
| 23 | .21956 | 4.55458 | .23793 | 4.20298 | .25645 | 3.89045 | .27513 | 3.63461 | 37 |
| 24 | .21986 | 4.54826 | .23823 | 4.19756 | .25676 | 3.89474 | .27545 | 3.63048 | 36 |
| 25 | .22017 | 4.54196 | .23854 | 4.19215 | .25707 | 3.89004 | .27576 | 3.62636 | 35 |
| 26 | .22047 | 4.53568 | .23385 | 4.18675 | .25738 | 3.88536 | .27607 | 3.62224 | 34 |
| 27 | .22078 | 4.52941 | .23916 | 4.18137 | .25769 | 3.88068 | .27638 | 3.61814 | 33 |
| 28 | .22108 | 4.52316 | .23946 | 4.17600 | .25800 | 3.87601 | .27670 | 3.61405 | 32 |
| 29 | .22139 | 4.51693 | .23977 | 4.17064 | .25831 | 3.87136 | .27701 | 3.60996 | 31 |
| 30 | .22169 | 4.51071 | .24008 | 4.16530 | .25862 | 3.86671 | .27732 | 3.60588 | 30 |
| 31 | .22200 | 4.50451 | .24039 | 4.15997 | .25893 | 3.86208 | .27764 | 3.60181 | 29 |
| 32 | .22231 | 4.49832 | .24069 | 4.15465 | .25924 | 3.85745 | .27795 | 3.59775 | 28 |
| 33 | .22261 | 4.49215 | .24100 | 4.14934 | .25955 | 3.85284 | .27826 | 3.59370 | 27 |
| 34 | .22292 | 4.48600 | .24131 | 4.14405 | .25986 | 3.84824 | .27858 | 3.58966 | 26 |
| 35 | .22322 | 4.47986 | .24162 | 4.13877 | .26017 | 3.84364 | .27889 | 3.58562 | 25 |
| 36 | .22353 | 4.47374 | .24193 | 4.13350 | .26048 | 3.83906 | .27921 | 3.58160 | 24 |
| 37 | .22383 | 4.46764 | .24223 | 4.12825 | .26079 | 3.83449 | .27952 | 3.57758 | 23 |
| 38 | .22414 | 4.46155 | .24254 | 4.12301 | .26110 | 3.82992 | .27983 | 3.57357 | 22 |
| 39 | .22444 | 4.45548 | .24285 | 4.11778 | .26141 | 3.82537 | .28015 | 3.56957 | 21 |
| 40 | .22475 | 4.44942 | .24316 | 4.11256 | .26172 | 3.82083 | .28046 | 3.56557 | 20 |
| 41 | .22505 | 4.44338 | .24347 | 4.10736 | .26203 | 3.81630 | .28077 | 3.56159 | 19 |
| 42 | .22536 | 4.43735 | .24377 | 4.10216 | .26235 | 3.81177 | .28109 | 3.55761 | 18 |
| 43 | .22567 | 4.43134 | .24408 | 4.09699 | .26266 | 3.80726 | .28140 | 3.55364 | 17 |
| 44 | .22597 | 4.42534 | .24439 | 4.09182 | .26297 | 3.80276 | .28172 | 3.54968 | 16 |
| 45 | .22628 | 4.41936 | .24470 | 4.08666 | .26328 | 3.79827 | .28203 | 3.54573 | 15 |
| 46 | .22658 | 4.41340 | .24501 | 4.08152 | .26359 | 3.79378 | .28234 | 3.54179 | 14 |
| 47 | .22689 | 4.40745 | .24532 | 4.07639 | .26390 | 3.78931 | .28266 | 3.53785 | 13 |
| 48 | .22719 | 4.40152 | .24562 | 4.07127 | .26421 | 3.78485 | .28297 | 3.53393 | 12 |
| 49 | .22750 | 4.39560 | .24593 | 4.06616 | .26452 | 3.78040 | .28329 | 3.53001 | 11 |
| 50 | .22781 | 4.38969 | .24624 | 4.06107 | .26483 | 3.77595 | .28360 | 3.52609 | 10 |
| 51 | .22811 | 4.38381 | .24655 | 4.05599 | .26515 | 3.77152 | .28391 | 3.52219 | 9 |
| 52 | .22842 | 4.37793 | .24686 | 4.05092 | .26546 | 3.76709 | .28423 | 3.51829 | 8 |
| 53 | .22872 | 4.37207 | .24717 | 4.04586 | .26577 | 3.76268 | .28454 | 3.51441 | 7 |
| 54 | .22903 | 4.36623 | .24747 | 4.04081 | .26608 | 3.75828 | .28486 | 3.51053 | 6 |
| 55 | .22934 | 4.36040 | .24778 | 4.03578 | .26639 | 3.75388 | .28517 | 3.50666 | 5 |
| 56 | .22964 | 4.35459 | .24809 | 4.03076 | .26670 | 3.74950 | .28549 | 3.50279 | 4 |
| 57 | .22995 | 4.34879 | .24840 | 4.02574 | .26701 | 3.74512 | .28580 | 3.49894 | 3 |
| 58 | .23026 | 4.34300 | .24871 | 4.02074 | .26733 | 3.74075 | .28612 | 3.49509 | 2 |
| 59 | .23056 | 4.33723 | .24902 | 4.01576 | .26764 | 3.73640 | .28643 | 3.49125 | 1 |
| 60 | .23087 | 4.33148 | .24933 | 4.01078 | .26795 | 3.73205 | .28675 | 3.48741 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 77° | | 76° | | 75° | | 74° | | |

| ′ | 16° | | 17° | | 18° | | 19° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .28675 | 3.48741 | .30573 | 3.27085 | .32492 | 3.07768 | .34433 | 2.90421 | 60 |
| 1 | .28706 | 3.48359 | .30605 | 3.26745 | .32524 | 3.07464 | .34465 | 2.90147 | 59 |
| 2 | .28738 | 3.47977 | .30637 | 3.26406 | .32556 | 3.07160 | .34498 | 2.89873 | 58 |
| 3 | .28769 | 3.47596 | .30669 | 3.26067 | .32588 | 3.06857 | .34530 | 2.89600 | 57 |
| 4 | .28800 | 3.47216 | .30700 | 3.25729 | .32621 | 3.06554 | .34563 | 2.89327 | 56 |
| 5 | .28832 | 3.46837 | .30732 | 3.25392 | .32653 | 3.06252 | .34596 | 2.89055 | 55 |
| 6 | .28864 | 3.46458 | .30764 | 3.25055 | .32685 | 3.05950 | .34628 | 2.88783 | 54 |
| 7 | .28895 | 3.46080 | .30796 | 3.24719 | .32717 | 3.05649 | .34661 | 2.88511 | 53 |
| 8 | .28927 | 3.45703 | .30828 | 3.24383 | .32749 | 3.05349 | .34693 | 2.88240 | 52 |
| 9 | .28958 | 3.45327 | .30860 | 3.24049 | .32782 | 3.05049 | .34726 | 2.87970 | 51 |
| 10 | .28990 | 3.44951 | .30891 | 3.23714 | .32814 | 3.04749 | .34758 | 2 87700 | 50 |
| 11 | .29021 | 3.44576 | .30923 | 3.23381 | .32846 | 3.04450 | .34791 | 2.87430 | 49 |
| 12 | .29053 | 3.44202 | .30955 | 3.23048 | .32878 | 3.04152 | .34824 | 2.87161 | 48 |
| 13 | .29084 | 3.43829 | .30987 | 3.22715 | .32911 | 3.03854 | .34856 | 2.86892 | 47 |
| 14 | .29116 | 3.43456 | .31019 | 3.22384 | .32943 | 3.03556 | .34889 | 2.86624 | 46 |
| 15 | .29147 | 3.43084 | .31051 | 3.22053 | .32975 | 3.03260 | .34922 | 2.86356 | 45 |
| 16 | .29179 | 3.42713 | .31083 | 3.21722 | .33007 | 3.02963 | .34954 | 2.86089 | 44 |
| 17 | .29210 | 3.42343 | .31115 | 3.21392 | .33040 | 3.02667 | .34987 | 2.85822 | 43 |
| 18 | .29242 | 3.41973 | .31147 | 3.21063 | .33072 | 3.02372 | .35020 | 2.85555 | 42 |
| 19 | .29274 | 3.41604 | .31178 | 3.20734 | .33104 | 3.02077 | .35052 | 2.85289 | 41 |
| 20 | .29305 | 3.41236 | .31210 | 3.20406 | .33136 | 3.01783 | .35085 | 2.85023 | 40 |
| 21 | .29337 | 3.40869 | .31242 | 3.20079 | .33169 | 3.01489 | .35118 | 2.84758 | 39 |
| 22 | .29368 | 3.40502 | .31274 | 3.19752 | .33201 | 3.01196 | .35150 | 2.84494 | 38 |
| 23 | .29400 | 3.40136 | .31306 | 3.19426 | .33233 | 3.00903 | .35183 | 2.84229 | 37 |
| 24 | .29432 | 3.39771 | .31338 | 3.19100 | .33266 | 3.00611 | .35216 | 2.83965 | 36 |
| 25 | .29463 | 3.39406 | .31370 | 3.18775 | .33298 | 3.00319 | .35248 | 2.83702 | 35 |
| 26 | .29495 | 3.39042 | .31402 | 3.18451 | .33330 | 3.00028 | .35281 | 2.83439 | 34 |
| 27 | .29526 | 3.38679 | .31434 | 3.18127 | .33363 | 2.99738 | .35314 | 2.83176 | 33 |
| 28 | .29558 | 3.38317 | .31466 | 3.17804 | .33395 | 2.99447 | .35346 | 2.82914 | 32 |
| 29 | .29590 | 3.37955 | .31498 | 3.17481 | .33427 | 2.99158 | .35379 | 2.82653 | 31 |
| 30 | .29621 | 3.37594 | .31530 | 3.17159 | .33460 | 2.98868 | .35412 | 2.82391 | 30 |
| 31 | .29653 | 3.37234 | .31562 | 3.16838 | .33492 | 2.98580 | .35445 | 2.82130 | 29 |
| 32 | .29685 | 3.36875 | .31594 | 3.16517 | .33524 | 2.98292 | .35477 | 2.81870 | 28 |
| 33 | .29716 | 3.36516 | .31626 | 3.16197 | .33557 | 2.98004 | .35510 | 2.81610 | 27 |
| 34 | .29748 | 3.36158 | .31658 | 3.15877 | .33589 | 2.97717 | .35543 | 2.81350 | 26 |
| 35 | .29780 | 3.35800 | .31690 | 3.15558 | .33621 | 2.97430 | .35576 | 2.81091 | 25 |
| 36 | .29811 | 3.35443 | .31722 | 3.15240 | .33654 | 2.97144 | .35608 | 2.80833 | 24 |
| 37 | .29843 | 3.35087 | .31754 | 3.14922 | .33686 | 2.96858 | .35641 | 2.80574 | 23 |
| 38 | .29875 | 3.34732 | .31786 | 3.14605 | .33718 | 2.96573 | .35674 | 2.80316 | 22 |
| 39 | .29906 | 3.34377 | .31818 | 3.14288 | .33751 | 2.96288 | .35707 | 2.80059 | 21 |
| 40 | .29938 | 3.34023 | .31850 | 3.13972 | .33783 | 2.96004 | .35740 | 2.79802 | 20 |
| 41 | .29970 | 3.33670 | .31882 | 3.13656 | .33816 | 2.95721 | .35772 | 2.79545 | 19 |
| 42 | .30001 | 3.33317 | .31914 | 3.13341 | .33848 | 2.95437 | .35805 | 2.79289 | 18 |
| 43 | .30033 | 3.32965 | .31946 | 3.13027 | .33881 | 2.95155 | .35838 | 2.79033 | 17 |
| 44 | .30065 | 3.32614 | .31978 | 3.12713 | .33913 | 2.94872 | .35871 | 2.78778 | 16 |
| 45 | .30097 | 3.32264 | .32010 | 3.12400 | .33945 | 2.94591 | .35904 | 2.78523 | 15 |
| 46 | .30128 | 3.31914 | .32042 | 3.12087 | .33978 | 2.94309 | .35937 | 2.78269 | 14 |
| 47 | .30160 | 3.31565 | .32074 | 3.11775 | .34010 | 2.94028 | .35969 | 2.78014 | 13 |
| 48 | .30192 | 3.31216 | .32106 | 3.11464 | .34043 | 2.93748 | .36002 | 2.77761 | 12 |
| 49 | .30224 | 3.30868 | .32139 | 3.11153 | .34075 | 2.93468 | .36035 | 2.77507 | 11 |
| 50 | .30255 | 3.30521 | .32171 | 3.10842 | .34108 | 2.93189 | .36068 | 2.77254 | 10 |
| 51 | .30287 | 3.30174 | .32203 | 3.10532 | .34140 | 2.92910 | .36101 | 2.77002 | 9 |
| 52 | .30319 | 3.29829 | .32235 | 3.10223 | .34173 | 2.92632 | .36134 | 2.76750 | 8 |
| 53 | .30351 | 3.29483 | .32267 | 3.09914 | .34205 | 2.92354 | .36167 | 2.76498 | 7 |
| 54 | .30382 | 3.29139 | .32299 | 3.09606 | .34238 | 2.92076 | .36199 | 2.76247 | 6 |
| 55 | .30414 | 3.28795 | .32331 | 3.09298 | .34270 | 2.91799 | .36232 | 2.75996 | 5 |
| 56 | .30446 | 3.28452 | .32363 | 3.08991 | .34303 | 2.91523 | .36265 | 2.75746 | 4 |
| 57 | .30478 | 3.28109 | .32396 | 3.08685 | .34335 | 2.91246 | .36298 | 2.75496 | 3 |
| 58 | .30509 | 3.27767 | .32428 | 3.08379 | .34368 | 2.90971 | .36331 | 2.75246 | 2 |
| 59 | .30541 | 3.27426 | .32460 | 3.08073 | .34400 | 2.90696 | .36364 | 2.74997 | 1 |
| 60 | .30573 | 3.27085 | .32492 | 3.07768 | .34433 | 2.90421 | .36397 | 2.74748 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 73° | | 72° | | 71° | | 70° | | |

| ′ | 20° | | 21° | | 22° | | 23° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .36397 | 2.74748 | .38386 | 2.60509 | .40403 | 2.47509 | .42447 | 2.35585 | 60 |
| 1 | .36430 | 2.74499 | .38420 | 2.60283 | .40436 | 2.47302 | .42482 | 2.35395 | 59 |
| 2 | .36463 | 2.74251 | .38453 | 2.60057 | .40470 | 2.47095 | .42516 | 2.35205 | 58 |
| 3 | .36496 | 2.74004 | .38487 | 2.59831 | .40504 | 2.46888 | .42551 | 2.35015 | 57 |
| 4 | .36529 | 2.73756 | .38520 | 2.59606 | .40538 | 2.46682 | .42585 | 2.34825 | 56 |
| 5 | .36562 | 2.73509 | .38553 | 2.59381 | .40572 | 2.46476 | .42619 | 2.34636 | 55 |
| 6 | .36595 | 2.73263 | .38587 | 2.59156 | .40606 | 2.46270 | .42654 | 2.34447 | 54 |
| 7 | .36628 | 2.73017 | .38620 | 2.58932 | .40640 | 2.46065 | .42688 | 2.34258 | 53 |
| 8 | .36661 | 2.72771 | .38654 | 2.58708 | .40674 | 2.45860 | .42722 | 2.34069 | 52 |
| 9 | .36694 | 2.72526 | .38687 | 2.58484 | .40707 | 2.45655 | .42757 | 2.33881 | 51 |
| 10 | .36727 | 2.72281 | .38721 | 2.58261 | .40741 | 2.45451 | .42791 | 2.33693 | 50 |
| 11 | .36760 | 2.72036 | .38754 | 2.58038 | .40775 | 2.45246 | .42826 | 2.33505 | 49 |
| 12 | .36793 | 2.71792 | .38787 | 2.57815 | .40809 | 2.45043 | .42860 | 2.33317 | 48 |
| 13 | .36826 | 2.71548 | .38821 | 2.57593 | .40843 | 2.44839 | .42894 | 2.33130 | 47 |
| 14 | .36859 | 2.71305 | .38854 | 2.57371 | .40877 | 2.44636 | .42929 | 2.32943 | 46 |
| 15 | .36892 | 2.71062 | .38888 | 2.57150 | .40911 | 2.44433 | .42963 | 2.32756 | 45 |
| 16 | .36925 | 2.70819 | .38921 | 2.56928 | .40945 | 2.44230 | .42998 | 2.32570 | 44 |
| 17 | .36958 | 2.70577 | .38955 | 2.56707 | .40979 | 2.44027 | .43032 | 2.32383 | 43 |
| 18 | .36991 | 2.70335 | .38988 | 2.56487 | .41013 | 2.43825 | .43067 | 2.32197 | 42 |
| 19 | .37024 | 2.70094 | .39022 | 2.56266 | .41047 | 2.43623 | .43101 | 2.32012 | 41 |
| 20 | .37057 | 2.69853 | .39055 | 2.56046 | .41081 | 2.43422 | .43136 | 2.31826 | 40 |
| 21 | .37090 | 2.69612 | .39089 | 2.55827 | .41115 | 2.43220 | .43170 | 2.31641 | 39 |
| 22 | .37123 | 2.69371 | .39122 | 2.55608 | .41149 | 2.43019 | .43205 | 2.31456 | 38 |
| 23 | .37157 | 2.69131 | .39156 | 2.55389 | .41183 | 2.42819 | .43239 | 2.31271 | 37 |
| 24 | .37190 | 2.68892 | .39190 | 2.55170 | .41217 | 2.42618 | .43274 | 2.31086 | 36 |
| 25 | .37223 | 2.68653 | .39223 | 2.54952 | .41251 | 2.42418 | .43308 | 2.30902 | 35 |
| 26 | .37256 | 2.68414 | .39257 | 2.54734 | .41285 | 2.42218 | .43343 | 2.30718 | 34 |
| 27 | .37289 | 2.68175 | .39290 | 2.54516 | .41319 | 2.42019 | .43378 | 2.30534 | 33 |
| 28 | .37322 | 2 67937 | .39324 | 2.54299 | .41353 | 2.41819 | .43412 | 2.30351 | 32 |
| 29 | .37355 | 2.67700 | .39357 | 2.54082 | .41387 | 2.41620 | .43447 | 2.30167 | 31 |
| 30 | .37388 | 2.67462 | .39391 | 2.53865 | .41421 | 2.41421 | .43481 | 2.29984 | 30 |
| 31 | .37422 | 2.67225 | .39425 | 2.53648 | .41455 | 2.41223 | .43516 | 2.29801 | 29 |
| 32 | .37455 | 2.66989 | .39458 | 2.53432 | .41490 | 2.41025 | .43550 | 2.29619 | 28 |
| 33 | .37488 | 2.66752 | .39492 | 2.53217 | .41524 | 2.40827 | .43585 | 2.29437 | 27 |
| 34 | .37521 | 2.66516 | .39526 | 2.53001 | .41558 | 2.40629 | .43620 | 2.29254 | 26 |
| 35 | .37554 | 2.66281 | .39559 | 2.52786 | .41592 | 2.40432 | .43654 | 2.29073 | 25 |
| 36 | .37588 | 2.66046 | 39593 | 2.52571 | .41626 | 2.40235 | .43689 | 2.28891 | 24 |
| 37 | .37621 | 2.65811 | 39626 | 2.52357 | .41660 | 2.40038 | .43724 | 2.28710 | 23 |
| 38 | .37654 | 2.65576 | .39660 | 2.52142 | .41694 | 2.39841 | .43758 | 2.28528 | 22 |
| 39 | .37687 | 2.65342 | .39694 | 2.519[illegible] | .41728 | 2.39645 | .43793 | 2.28348 | 21 |
| 40 | .37720 | 2.65109 | .39727 | 2.51715 | .41763 | 2.39449 | .43828 | 2.28167 | 20 |
| 41 | .37754 | 2.64875 | .39761 | 2.51502 | .41797 | 2.39253 | .43862 | 2.27987 | 19 |
| 42 | .37787 | 2.64642 | .39795 | 2.51289 | .41831 | 2.39058 | .43897 | 2.27806 | 18 |
| 43 | .37820 | 2.64410 | .39829 | 2.51076 | .41865 | 2.38863 | .43932 | 2.27626 | 17 |
| 44 | .37853 | 2.64177 | .39862 | 2.50864 | 41899 | 2.38668 | .43966 | 2.27447 | 16 |
| 45 | .37887 | 2.63945 | .39896 | 2.50652 | .41933 | 2.38473 | .44001 | 2.27267 | 15 |
| 46 | .37920 | 2.63714 | .39930 | 2.50440 | .41968 | 2.38279 | .44036 | 2.27088 | 14 |
| 47 | .37953 | 2.63483 | .39963 | 2.50229 | .42002 | 2.38084 | .44071 | 2.26909 | 13 |
| 48 | .37986 | 2.63252 | .39997 | 2.50018 | .42036 | 2.37891 | .44105 | 2.26730 | 12 |
| 49 | .38020 | 2.63021 | .40031 | 2.49807 | .42070 | 2.37697 | .44140 | 2.26552 | 11 |
| 50 | .38053 | 2.62791 | .40065 | 2.49597 | .42105 | 2.37504 | .44175 | 2.26374 | 10 |
| 51 | .38086 | 2.62561 | .40098 | 2.49386 | .42139 | 2.37311 | .44210 | 2.26196 | 9 |
| 52 | .38120 | 2.62332 | .40132 | 2.49177 | .42173 | 2.37118 | .44244 | 2.26018 | 8 |
| 53 | .38153 | 2.62103 | .40166 | 2.48967 | .42207 | 2.36925 | .44279 | 2.25840 | 7 |
| 54 | .38186 | 2.61874 | .40200 | 2.48758 | .42242 | 2.36733 | .44314 | 2.25663 | 6 |
| 55 | .38220 | 2.61646 | .40234 | 2.48549 | .42276 | 2.36541 | .44349 | 2.25486 | 5 |
| 56 | .38253 | 2.61418 | .40267 | 2 48340 | .42310 | 2.36349 | .44384 | 2.25309 | 4 |
| 57 | .38286 | 2.61190 | .40301 | 2.48132 | .42345 | 2.36158 | .44418 | 2.25132 | 3 |
| 58 | .38320 | 2.60963 | .40335 | 2.47924 | .42379 | 2.35967 | .44453 | 2.24956 | 2 |
| 59 | .38353 | 2.60736 | .40369 | 2.47716 | .42413 | 2.35776 | .44488 | 2 24780 | 1 |
| 60 | .38386 | 2 60509 | .40403 | 2 47509 | .42447 | 2 35585 | .44523 | 2.24604 | 0 |
| | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 69° | | 68° | | 67° | | 66° | | |

| ′ | 24° | | 25° | | 26° | | 27° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .44523 | 2.24604 | .46631 | 2.14451 | .48773 | 2.05030 | .50953 | 1.96261 | 60 |
| 1 | .44558 | 2.24428 | .46666 | 2.14288 | .48809 | 2.04879 | .50989 | 1.96120 | 59 |
| 2 | .44593 | 2.24252 | .46702 | 2.14125 | .48845 | 2.04728 | .51026 | 1.95979 | 58 |
| 3 | .44627 | 2.24077 | .46737 | 2.13963 | .48881 | 2.04577 | .51063 | 1.95838 | 57 |
| 4 | .44662 | 2.23902 | .46772 | 2.13801 | .48917 | 2.04426 | .51099 | 1.95698 | 56 |
| 5 | .44697 | 2.23727 | .46808 | 2.13639 | .48953 | 2.04276 | .51136 | 1.95557 | 55 |
| 6 | .44732 | 2.23553 | .46843 | 2.13477 | .48989 | 2.04125 | .51173 | 1.95417 | 54 |
| 7 | .44767 | 2.23378 | .46879 | 2.13316 | .49026 | 2.03975 | .51209 | 1.95277 | 53 |
| 8 | .44802 | 2.23204 | .46914 | 2.13154 | .49062 | 2.03825 | .51246 | 1.95137 | 52 |
| 9 | .44837 | 2.23030 | .46950 | 2.12993 | .49098 | 2.03675 | .51283 | 1.94997 | 51 |
| 10 | .44872 | 2.22857 | .46985 | 2.12832 | .49134 | 2.03526 | .51319 | 1.94858 | 50 |
| 11 | .44907 | 2.22683 | .47021 | 2.12671 | .49170 | 2.03376 | .51356 | 1.94718 | 49 |
| 12 | .44942 | 2.22510 | .47056 | 2.12511 | .49206 | 2.03227 | .51393 | 1.94579 | 48 |
| 13 | .44977 | 2.22337 | .47092 | 2.12350 | .49242 | 2.03078 | .51430 | 1.94440 | 47 |
| 14 | .45012 | 2.22164 | .47128 | 2.12190 | .49278 | 2.02929 | .51467 | 1.94301 | 46 |
| 15 | .45047 | 2.21992 | .47163 | 2.12030 | .49315 | 2.02780 | .51503 | 1.94162 | 45 |
| 16 | .45082 | 2.21819 | .47199 | 2.11871 | .49351 | 2.02631 | .51540 | 1.94023 | 44 |
| 17 | .45117 | 2.21647 | .47234 | 2.11711 | .49387 | 2.02483 | .51577 | 1.93885 | 43 |
| 18 | .45152 | 2.21475 | .47270 | 2.11552 | .49423 | 2.02335 | .51614 | 1.93746 | 42 |
| 19 | .45187 | 2.21304 | .47305 | 2.11392 | .49459 | 2.02187 | .51651 | 1.93608 | 41 |
| 20 | .45222 | 2.21132 | .47341 | 2.11233 | .49495 | 2.02039 | .51688 | 1.93470 | 40 |
| 21 | .45257 | 2.20961 | .47377 | 2.11075 | .49532 | 2.01891 | .51724 | 1.93332 | 39 |
| 22 | .45292 | 2.20790 | .47412 | 2.10916 | .49568 | 2.01743 | .51761 | 1.93195 | 38 |
| 23 | .45327 | 2.20619 | .47448 | 2.10758 | .49604 | 2.01596 | .51798 | 1.93057 | 37 |
| 24 | .45362 | 2.20449 | .47483 | 2.10600 | .49640 | 2.01449 | .51835 | 1.92920 | 36 |
| 25 | .45397 | 2.20278 | .47519 | 2.10442 | .49677 | 2.01302 | .51872 | 1.92782 | 35 |
| 26 | .45432 | 2.20108 | .47555 | 2.10284 | .49713 | 2.01155 | .51909 | 1.92645 | 34 |
| 27 | .45467 | 2.19938 | .47590 | 2.10126 | .49749 | 2.01008 | .51946 | 1.92508 | 33 |
| 28 | .45502 | 2.19769 | .47626 | 2.09969 | .49786 | 2.00862 | .51983 | 1.92371 | 32 |
| 29 | .45538 | 2.19599 | .47662 | 2.09811 | .49822 | 2.00715 | .52020 | 1.92235 | 31 |
| 30 | .45573 | 2.19430 | .47698 | 2.09654 | .49858 | 2.00569 | .52057 | 1.92098 | 30 |
| 31 | .45608 | 2.19261 | .47733 | 2.09498 | .49894 | 2.00423 | .52094 | 1.91962 | 29 |
| 32 | .45643 | 2.19092 | .47769 | 2.09341 | .49931 | 2.00277 | .52131 | 1.91826 | 28 |
| 33 | .45678 | 2.18923 | .47805 | 2.09184 | .49967 | 2.00131 | .52168 | 1.91690 | 27 |
| 34 | .45713 | 2.18755 | .47840 | 2.09028 | .50004 | 1.99986 | .52205 | 1.91554 | 26 |
| 35 | .45748 | 2.18587 | .47876 | 2.08872 | .50040 | 1.99841 | .52242 | 1.91418 | 25 |
| 36 | .45784 | 2.18419 | .47912 | 2.08716 | .50076 | 1.99695 | .52279 | 1.91282 | 24 |
| 37 | .45819 | 2.18251 | .47948 | 2.08560 | .50113 | 1.99550 | .52316 | 1.91147 | 23 |
| 38 | .45854 | 2.18084 | .47984 | 2.08405 | .50149 | 1.99406 | .52353 | 1.91012 | 22 |
| 39 | .45889 | 2.17916 | .48019 | 2.08250 | .50185 | 1.99261 | .52390 | 1.90876 | 21 |
| 40 | .45924 | 2.17749 | .48055 | 2.08094 | .50222 | 1.99116 | .52427 | 1.90741 | 20 |
| 41 | .45960 | 2.17582 | .48091 | 2.07939 | .50258 | 1.98972 | .52464 | 1.90607 | 19 |
| 42 | .45995 | 2.17416 | .48127 | 2.07785 | .50295 | 1.98828 | .52501 | 1.90472 | 18 |
| 43 | .46030 | 2.17249 | .48163 | 2.07630 | .50331 | 1.98684 | .52538 | 1.90337 | 17 |
| 44 | .46065 | 2.17083 | .48198 | 2.07476 | .50368 | 1.98540 | .52575 | 1.90203 | 16 |
| 45 | .46101 | 2.16917 | .48234 | 2.07321 | .50404 | 1.98396 | .52613 | 1.90069 | 15 |
| 46 | .46136 | 2.16751 | .48270 | 2.07167 | .50441 | 1.98253 | .52650 | 1.89935 | 14 |
| 47 | .46171 | 2.16585 | .48306 | 2.07014 | .50477 | 1.98110 | .52687 | 1.89801 | 13 |
| 48 | .46206 | 2.16420 | .48342 | 2.06860 | .50514 | 1.97966 | .52724 | 1.89667 | 12 |
| 49 | .46242 | 2.16255 | .48378 | 2.06706 | .50550 | 1.97823 | .52761 | 1.89533 | 11 |
| 50 | .46277 | 2.16090 | .48414 | 2.06553 | .50587 | 1.97681 | .52798 | 1.89400 | 10 |
| 51 | .46312 | 2.15925 | .48450 | 2.06400 | .50623 | 1.97538 | .52836 | 1.89266 | 9 |
| 52 | .46348 | 2.15760 | .48486 | 2.06247 | .50660 | 1.97395 | .52873 | 1.89133 | 8 |
| 53 | .46383 | 2.15596 | .48521 | 2.06094 | .50696 | 1.97253 | .52910 | 1.89000 | 7 |
| 54 | .46418 | 2.15432 | .48557 | 2.05942 | .50733 | 1.97111 | .52947 | 1.88867 | 6 |
| 55 | .46454 | 2.15268 | .48593 | 2.05790 | .50769 | 1.96969 | .52985 | 1.88734 | 5 |
| 56 | .46489 | 2.15104 | .48629 | 2.05637 | .50806 | 1.96827 | .53022 | 1.88602 | 4 |
| 57 | .46525 | 2.14940 | .48665 | 2.05485 | .50843 | 1.96685 | .53059 | 1.88469 | 3 |
| 58 | .46560 | 2.14777 | .48701 | 2.05333 | .50879 | 1.96544 | .53096 | 1.88337 | 2 |
| 59 | .46595 | 2.14614 | .48737 | 2.05182 | .50916 | 1.96402 | .53134 | 1.88205 | 1 |
| 60 | .46631 | 2.14451 | .48773 | 2.05030 | .50953 | 1.96261 | .53171 | 1.88073 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 65° | | 64° | | 63° | | 62° | | |

| ′ | 28° Tang | 28° Cotang | 29° Tang | 29° Cotang | 30° Tang | 30° Cotang | 31° Tang | 31° Cotang | ′ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 60 |
| 1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 59 |
| 2 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 58 |
| 3 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 57 |
| 4 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 56 |
| 5 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 55 |
| 6 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65772 | 54 |
| 7 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65663 | 53 |
| 8 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65554 | 52 |
| 9 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65445 | 51 |
| 10 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65337 | 50 |
| 11 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65228 | 49 |
| 12 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65120 | 48 |
| 13 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 65011 | 47 |
| 14 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 46 |
| 15 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 64795 | 45 |
| 16 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 44 |
| 17 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 64579 | 43 |
| 18 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 64471 | 42 |
| 19 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 64363 | 41 |
| 20 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.64256 | 40 |
| 21 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 39 |
| 22 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 64041 | 38 |
| 23 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 37 |
| 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 36 |
| 25 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 63719 | 35 |
| 26 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 63612 | 34 |
| 27 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 63505 | 33 |
| 28 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 32 |
| 29 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.63292 | 31 |
| 30 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 63185 | 30 |
| 31 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 63079 | 29 |
| 32 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 62972 | 28 |
| 33 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 27 |
| 34 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 62760 | 26 |
| 35 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 62654 | 25 |
| 36 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 62548 | 24 |
| 37 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 62442 | 23 |
| 38 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 22 |
| 39 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 21 |
| 40 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 62125 | 20 |
| 41 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 62019 | 19 |
| 42 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 61914 | 18 |
| 43 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 61808 | 17 |
| 44 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 61703 | 16 |
| 45 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 61598 | 15 |
| 46 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.61493 | 14 |
| 47 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 61388 | 13 |
| 48 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 61283 | 12 |
| 49 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.61179 | 11 |
| 50 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.61074 | 10 |
| 51 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60970 | 9 |
| 52 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60865 | 8 |
| 53 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60761 | 7 |
| 54 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60657 | 6 |
| 55 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60553 | 5 |
| 56 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60449 | 4 |
| 57 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.60345 | 3 |
| 58 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60241 | 2 |
| 59 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.60137 | 1 |
| 60 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1 60033 | 0 |
| ′ | 61° Cotang | 61° Tang | 60° Cotang | 60° Tang | 59° Cotang | 59° Tang | 58° Cotang | 58° Tang | ′ |

| ′ | 32° | | 33° | | 34° | | 35° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .62487 | 1.60033 | .64941 | 1.53986 | .67451 | 1.48256 | .70021 | 1.42815 | 60 |
| 1 | .62527 | 1.59930 | .64982 | 1.53888 | .67493 | 1.48163 | .70064 | 1.42726 | 59 |
| 2 | .62568 | 1.59826 | .65024 | 1.53791 | .67536 | 1.48070 | .70107 | 1.42638 | 58 |
| 3 | .62608 | 1.59723 | .65065 | 1.53693 | .67578 | 1.47977 | .70151 | 1.42550 | 57 |
| 4 | .62649 | 1.59620 | .65106 | 1.53595 | .67620 | 1.47885 | .70194 | 1.42462 | 56 |
| 5 | .62689 | 1.59517 | .65148 | 1.53497 | .67663 | 1.47792 | .70238 | 1.42374 | 55 |
| 6 | .62730 | 1.59414 | .65189 | 1.53400 | .67705 | 1.47699 | .70281 | 1.42286 | 54 |
| 7 | .62770 | 1.59311 | .65231 | 1.53302 | .67748 | 1.47607 | .70325 | 1.42198 | 53 |
| 8 | .62811 | 1.59208 | .65272 | 1.53205 | .67790 | 1.47514 | .70368 | 1.42110 | 52 |
| 9 | .62852 | 1.59105 | .65314 | 1.53107 | .67832 | 1.47422 | .70412 | 1.42022 | 51 |
| 10 | .62892 | 1.59002 | .65355 | 1.53010 | .67875 | 1.47330 | .70455 | 1.41934 | 50 |
| 11 | .62933 | 1.58900 | .65397 | 1.52913 | .67917 | 1.47238 | .70499 | 1.41847 | 49 |
| 12 | .62973 | 1.58797 | .65438 | 1.52816 | .67960 | 1.47146 | .70542 | 1.41759 | 48 |
| 13 | .63014 | 1.58695 | .65480 | 1.52719 | .68002 | 1.47053 | .70586 | 1.41672 | 47 |
| 14 | .63055 | 1.58593 | .65521 | 1.52622 | .68045 | 1.46962 | .70629 | 1.41584 | 46 |
| 15 | .63095 | 1.58490 | .65563 | 1.52525 | .68088 | 1.46870 | .70673 | 1.41497 | 45 |
| 16 | .63136 | 1.58388 | .65604 | 1.52429 | .68130 | 1.46778 | .70717 | 1.41409 | 44 |
| 17 | .63177 | 1.58286 | .65646 | 1.52332 | .68173 | 1.46686 | .70760 | 1.41322 | 43 |
| 18 | .63217 | 1.58184 | .65688 | 1.52235 | .68215 | 1.46595 | .70804 | 1.41235 | 42 |
| 19 | .63258 | 1.58083 | .65729 | 1.52139 | .68258 | 1.46503 | .70848 | 1.41148 | 41 |
| 20 | .63299 | 1.57981 | .65771 | 1.52043 | .68301 | 1.46411 | .70891 | 1.41061 | 40 |
| 21 | .63340 | 1.57879 | .65813 | 1.51946 | .68343 | 1.46320 | .70935 | 1.40974 | 39 |
| 22 | .63380 | 1.57778 | .65854 | 1.51850 | .68386 | 1.46229 | .70979 | 1.40887 | 38 |
| 23 | .63421 | 1.57676 | .65896 | 1.51754 | .68429 | 1.46137 | .71023 | 1.40800 | 37 |
| 24 | .63462 | 1.57575 | .65938 | 1.51658 | .68471 | 1.46046 | .71066 | 1.40714 | 36 |
| 25 | .63503 | 1.57474 | .65980 | 1.51562 | .68514 | 1.45955 | .71110 | 1.40627 | 35 |
| 26 | .63544 | 1.57372 | .66021 | 1.51466 | .68557 | 1.45864 | .71154 | 1.40540 | 34 |
| 27 | .63584 | 1.57271 | .66063 | 1.51370 | .68600 | 1.45773 | .71198 | 1.40454 | 33 |
| 28 | .63625 | 1.57170 | .66105 | 1.51275 | .68642 | 1.45682 | .71242 | 1.40367 | 32 |
| 29 | .63666 | 1.57069 | .66147 | 1.51179 | .68685 | 1.45592 | .71285 | 1.40281 | 31 |
| 30 | .63707 | 1.56969 | .66189 | 1.51084 | .68728 | 1.45501 | .71329 | 1.40195 | 30 |
| 31 | .63748 | 1.56868 | .66230 | 1.50988 | .68771 | 1.45410 | .71373 | 1.40109 | 29 |
| 32 | .63789 | 1.56767 | .66272 | 1.50893 | .68814 | 1.45320 | .71417 | 1.40022 | 28 |
| 33 | .63830 | 1.56667 | .66314 | 1.50797 | .68857 | 1.45229 | .71461 | 1.39936 | 27 |
| 34 | .63871 | 1.56566 | .66356 | 1.50702 | .68900 | 1.45139 | .71505 | 1.39850 | 26 |
| 35 | .63912 | 1.56466 | .66398 | 1.50607 | .68942 | 1.45049 | .71549 | 1.39764 | 25 |
| 36 | .63953 | 1.56366 | .66440 | 1.50512 | .68985 | 1.44958 | .71593 | 1.39679 | 24 |
| 37 | .63994 | 1.56265 | .66482 | 1.50417 | .69028 | 1.44868 | .71637 | 1.39593 | 23 |
| 38 | .64035 | 1.56165 | .66524 | 1.50322 | .69071 | 1.44778 | .71681 | 1.39507 | 22 |
| 39 | .64076 | 1.56065 | .66566 | 1.50228 | .69114 | 1.44688 | .71725 | 1.39421 | 21 |
| 40 | .64117 | 1.55966 | .66608 | 1.50133 | .69157 | 1.44598 | .71769 | 1.39336 | 20 |
| 41 | .64158 | 1.55866 | .66650 | 1.50038 | .69200 | 1.44508 | .71813 | 1.39250 | 19 |
| 42 | .64199 | 1.55766 | .66692 | 1.49944 | .69243 | 1.44418 | .71857 | 1.39165 | 18 |
| 43 | .64240 | 1.55666 | .66734 | 1.49849 | .69286 | 1.44329 | .71901 | 1.39079 | 17 |
| 44 | .64281 | 1.55567 | .66776 | 1.49755 | .69329 | 1.44239 | .71946 | 1.38994 | 13 |
| 45 | .64322 | 1.55467 | .66818 | 1.49661 | .69372 | 1.44149 | .71990 | 1.38909 | 15 |
| 46 | .64363 | 1.55368 | .66860 | 1.49566 | .69416 | 1.44060 | .72034 | 1.38824 | 14 |
| 47 | .64404 | 1.55269 | .66902 | 1.49472 | .69459 | 1.43970 | .72078 | 1.38738 | 13 |
| 48 | .64446 | 1.55170 | .66944 | 1.49378 | .69502 | 1.43881 | .72122 | 1.38653 | 12 |
| 49 | .64487 | 1.55071 | .66986 | 1.49284 | .69545 | 1.43792 | .72167 | 1.38568 | 11 |
| 50 | .64528 | 1.54972 | .67028 | 1.49190 | .69588 | 1.43703 | .72211 | 1.38484 | 10 |
| 51 | .64569 | 1.54873 | .67071 | 1.49097 | .69631 | 1.43614 | .72255 | 1.38399 | 9 |
| 52 | .64610 | 1.54774 | .67113 | 1.49003 | .69675 | 1.43525 | .72299 | 1.38314 | 8 |
| 53 | .64652 | 1.54675 | .67155 | 1.48909 | .69718 | 1.43436 | .72344 | 1.38229 | 7 |
| 54 | .64693 | 1.54576 | .67197 | 1.48816 | .69761 | 1.43347 | .72388 | 1.38145 | 6 |
| 55 | .64734 | 1.54478 | .67239 | 1.48722 | .69804 | 1.43258 | .72432 | 1.38060 | 5 |
| 56 | .64775 | 1.54379 | .67282 | 1.48629 | .69847 | 1.43169 | .72477 | 1.37976 | 4 |
| 57 | .64817 | 1.54281 | .67324 | 1.48536 | .69891 | 1.43080 | .72521 | 1.37891 | 3 |
| 58 | .64858 | 1.54183 | .67366 | 1.48442 | .69934 | 1.42992 | .72565 | 1.37807 | 2 |
| 59 | .64899 | 1.54085 | .67409 | 1.48349 | .69977 | 1.42903 | .72610 | 1.37722 | 1 |
| 60 | .64941 | 1.53986 | .67451 | 1.48256 | .70021 | 1.42815 | .72654 | 1.37638 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
| | 57° | | 56° | | 55° | | 54° | | |

| ′ | 36° | | 37° | | 38° | | 39° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | |
| 0 | .72654 | 1.37638 | .75355 | 1.32704 | .78129 | 1.27994 | .80978 | 1.23490 | 60 |
| 1 | .72699 | 1.37554 | .75401 | 1.32624 | .78175 | 1.27917 | .81027 | 1.23416 | 59 |
| 2 | .72743 | 1.37470 | .75447 | 1.32544 | .78222 | 1.27841 | .81075 | 1.23343 | 58 |
| 3 | .72788 | 1.37386 | .75492 | 1.32464 | .78269 | 1.27764 | .81123 | 1.23270 | 57 |
| 4 | 72832 | 1.37302 | .75538 | 1.32384 | .78316 | 1.27688 | .81171 | 1.23196 | 56 |
| 5 | .72877 | 1.37218 | .75584 | 1.32304 | .78363 | 1.27611 | .81220 | 1.23123 | 55 |
| 6 | .72921 | 1.37134 | .75629 | 1.32224 | .78410 | 1.27535 | .81268 | 1.23050 | 54 |
| 7 | .72966 | 1.37050 | .75675 | 1.32144 | .78457 | 1.27458 | .81316 | 1.22977 | 53 |
| 8 | .73010 | 1.36967 | .75721 | 1.32064 | .78504 | 1.27382 | .81364 | 1.22904 | 52 |
| 9 | .73055 | 1.36883 | .75767 | 1.31984 | .78551 | 1.27306 | .81413 | 1.22831 | 51 |
| 10 | .73100 | 1.36800 | .75812 | 1.31904 | .78598 | 1.27230 | .81461 | 1.22758 | 50 |
| 11 | .73144 | 1.36716 | .75858 | 1.31825 | .78645 | 1.27153 | .81510 | 1.22685 | 49 |
| 12 | .73189 | 1.36633 | .75904 | 1.31745 | .78692 | 1.27077 | .81558 | 1.22612 | 48 |
| 13 | .73234 | 1.36549 | .75950 | 1.31666 | .78739 | 1.27001 | .81606 | 1.22539 | 47 |
| 14 | .73278 | 1.36466 | .75996 | 1.31586 | .78786 | 1.26925 | .81655 | 1.22467 | 46 |
| 15 | .73323 | 1.36383 | .76042 | 1.31507 | .78834 | 1.26849 | .81703 | 1.22394 | 45 |
| 16 | .73368 | 1.36300 | .76088 | 1.31427 | .78881 | 1.26774 | .81752 | 1.22321 | 44 |
| 17 | .73413 | 1.36217 | .76134 | 1.31348 | .78928 | 1.26698 | .81800 | 1.22249 | 43 |
| 18 | .73457 | 1.36134 | .76180 | 1.31269 | .78975 | 1.26622 | .81849 | 1.22176 | 42 |
| 19 | .73502 | 1.36051 | .76226 | 1.31190 | .79022 | 1.26546 | .81898 | 1.22104 | 41 |
| 20 | .73547 | 1.35968 | .76272 | 1.31110 | .79070 | 1.26471 | .81946 | 1.22031 | 40 |
| 21 | .73592 | 1.35885 | .76318 | 1.31031 | .79117 | 1.26395 | .81995 | 1.21959 | 39 |
| 22 | .73637 | 1.35802 | .76364 | 1.30952 | .79164 | 1.26319 | .82044 | 1.21886 | 38 |
| 23 | .73681 | 1.35719 | .76410 | 1.30873 | .79212 | 1.26244 | .82092 | 1.21814 | 37 |
| 24 | .73726 | 1.35637 | .76456 | 1.30795 | .79259 | 1.26169 | .82141 | 1.21742 | 36 |
| 25 | .73771 | 1.35554 | .76502 | 1.30716 | .79306 | 1.26093 | .82190 | 1.21670 | 35 |
| 26 | .73816 | 1.35472 | .76548 | 1.30637 | .79354 | 1.26018 | .82238 | 1.21598 | 34 |
| 27 | .73861 | 1.35389 | .76594 | 1.30558 | .79401 | 1.25943 | .82287 | 1.21526 | 33 |
| 28 | .73906 | 1.35307 | .76640 | 1.30480 | .79449 | 1.25867 | .82336 | 1.21454 | 32 |
| 29 | .73951 | 1.35224 | .76686 | 1.30401 | .79496 | 1.25792 | .82385 | 1.21382 | 31 |
| 30 | .73996 | 1.35142 | .76733 | 1.30323 | .79544 | 1.25717 | .82434 | 1.21310 | 30 |
| 31 | .74041 | 1.35060 | .76779 | 1.30244 | .79591 | 1.25642 | .82483 | 1.21238 | 29 |
| 32 | .74086 | 1.34978 | .76825 | 1.30166 | .79639 | 1.25567 | .82531 | 1.21166 | 28 |
| 33 | .74131 | 1.34896 | .76871 | 1.30087 | .79686 | 1.25492 | .82580 | 1.21094 | 27 |
| 34 | .74176 | 1.34814 | .76918 | 1.30009 | .79734 | 1.25417 | .82629 | 1.21023 | 26 |
| 35 | .74221 | 1.34732 | .76964 | 1.29931 | .79781 | 1.25343 | .82678 | 1.20951 | 25 |
| 36 | .74267 | 1.34650 | .77010 | 1.29853 | .79829 | 1.25268 | .82727 | 1.20879 | 24 |
| 37 | .74312 | 1.34568 | .77057 | 1.29775 | .79877 | 1.25193 | .82776 | 1.20808 | 23 |
| 38 | .74357 | 1.34487 | .77103 | 1.29696 | .79924 | 1.25118 | .82825 | 1.20736 | 22 |
| 39 | .74402 | 1.34405 | .77149 | 1.29618 | .79972 | 1.25044 | .82874 | 1.20665 | 21 |
| 40 | .74447 | 1.34323 | .77196 | 1.29541 | .80020 | 1.24969 | .82923 | 1.20593 | 20 |
| 41 | .74492 | 1.34242 | .77242 | 1.29463 | .80067 | 1.24895 | .82972 | 1.20522 | 19 |
| 42 | .74538 | 1.34160 | .77289 | 1.29385 | .80115 | 1.24820 | .83022 | 1.20451 | 18 |
| 43 | .74583 | 1.34079 | .77335 | 1.29307 | .80163 | 1.24746 | .83071 | 1.20379 | 17 |
| 44 | .74628 | 1.33998 | .77382 | 1.29229 | .80211 | 1.24672 | .83120 | 1.20308 | 16 |
| 45 | .74674 | 1.33916 | .77428 | 1.29152 | .80258 | 1.24597 | .83169 | 1.20237 | 15 |
| 46 | .74719 | 1.33835 | .77475 | 1.29074 | .80306 | 1.24523 | .83218 | 1.20166 | 14 |
| 47 | .74764 | 1.33754 | .77521 | 1.28997 | .80354 | 1.24449 | .83268 | 1.20095 | 13 |
| 48 | .74810 | 1.33673 | .77568 | 1.28919 | .80402 | 1.24375 | .83317 | 1.20024 | 12 |
| 49 | .74855 | 1.33592 | .77615 | 1.28842 | .80450 | 1.24301 | .83366 | 1.19953 | 11 |
| 50 | .74900 | 1.33511 | .77661 | 1.28764 | .80498 | 1.24227 | .83415 | 1.19882 | 10 |
| 51 | .74946 | 1.33430 | .77708 | 1.28687 | .80546 | 1.24153 | .83465 | 1.19811 | 9 |
| 52 | .74991 | 1.33349 | .77754 | 1.28610 | .80594 | 1.24079 | .83514 | 1.19740 | 8 |
| 53 | .75037 | 1.33268 | .77801 | 1.28533 | .80642 | 1.24005 | .83564 | 1.19669 | 7 |
| 54 | .75082 | 1.33187 | .77848 | 1.28456 | .80690 | 1.23931 | .83613 | 1.19599 | 6 |
| 55 | .75128 | 1.33107 | .77895 | 1.28379 | .80738 | 1.23858 | .83662 | 1.19528 | 5 |
| 56 | .75173 | 1.33026 | .77941 | 1.28302 | .80786 | 1.23784 | .83712 | 1.19457 | 4 |
| 57 | .75219 | 1.32946 | .77988 | 1.28225 | .80834 | 1.23710 | .83761 | 1.19387 | 3 |
| 58 | .75264 | 1.32865 | .78035 | 1.28148 | .80882 | 1.23637 | .83811 | 1.19316 | 2 |
| 59 | .75310 | 1.32785 | .78082 | 1.28071 | .80930 | 1.23563 | .83860 | 1.19246 | 1 |
| 60 | .75355 | 1.32704 | .78129 | 1.27994 | .80978 | 1.23490 | .83910 | 1.19175 | 0 |
| | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | |
| ′ | 53° | | 52° | | 51° | | 50° | | ′ |

| ′ | 40° |  | 41° |  | 42° |  | 43° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang |  |
| 0 | .83910 | 1.19175 | .86929 | 1.15037 | .90040 | 1.11061 | .93252 | 1.07237 | 60 |
| 1 | .83960 | 1.19105 | .86980 | 1.14969 | .90093 | 1.10996 | .93306 | 1.07174 | 59 |
| 2 | .84009 | 1.19035 | .87031 | 1:14902 | .90146 | 1.10931 | .93360 | 1.07112 | 58 |
| 3 | .84059 | 1.18964 | .87082 | 1.14834 | .90199 | 1.10867 | .93415 | 1.07049 | 57 |
| 4 | .84108 | 1.18894 | .87133 | 1.14767 | .90251 | 1.10802 | .93469 | 1.06987 | 56 |
| 5 | .84158 | 1.18824 | .87184 | 1.14699 | .90304 | 1.10737 | .93524 | 1.06925 | 55 |
| 6 | .84208 | 1.18754 | .87236 | 1.14632 | .90357 | 1.10672 | .93578 | 1.06862 | 54 |
| 7 | .84258 | 1.18684 | .87287 | 1.14565 | .90410 | 1.10607 | .93633 | 1.06800 | 53 |
| 8 | .84307 | 1.18614 | .87338 | 1.14498 | .90463 | 1.10543 | .93688 | 1.06738 | 52 |
| 9 | .84357 | 1.18544 | .87389 | 1.14430 | .90516 | 1.10478 | .93742 | 1.06676 | 51 |
| 10 | .84407 | 1.18474 | .87441 | 1.14363 | .90569 | 1.10414 | .93797 | 1.06613 | 50 |
| 11 | .84457 | 1.18404 | .87492 | 1.14296 | .90621 | 1.10349 | .93852 | 1.06551 | 49 |
| 12 | .84507 | 1.18334 | .87543 | 1.14229 | .90674 | 1.10285 | .93906 | 1.06489 | 48 |
| 13 | .84556 | 1.18264 | .87595 | 1.14162 | .90727 | 1.10220 | .93961 | 1.06427 | 47 |
| 14 | .84606 | 1.18194 | .87646 | 1.14095 | .90781 | 1.10156 | .94016 | 1.06365 | 46 |
| 15 | .84656 | 1.18125 | .87698 | 1.14028 | .90834 | 1.10091 | .94071 | 1.06303 | 45 |
| 16 | .84706 | 1.18055 | .87749 | 1.13961 | .90887 | 1.10027 | .94125 | 1.06241 | 44 |
| 17 | .84756 | 1.17986 | .87801 | 1.13894 | .90940 | 1.09963 | .94180 | 1.06179 | 43 |
| 18 | .84806 | 1.17916 | .87852 | 1.13828 | .90993 | 1.09899 | .94235 | 1.06117 | 42 |
| 19 | .84856 | 1.17846 | .87904 | 1.13761 | .91046 | 1.09834 | .94290 | 1.06056 | 41 |
| 20 | .84906 | 1.17777 | .87955 | 1.13694 | .91099 | 1.09770 | .94345 | 1.05994 | 40 |
| 21 | .84956 | 1.17708 | .88007 | 1.13627 | .91153 | 1.09706 | .94400 | 1.05932 | 39 |
| 22 | .85006 | 1.17638 | .88059 | 1.13561 | .91206 | 1.09642 | .94455 | 1.05870 | 38 |
| 23 | .85057 | 1.17569 | .88110 | 1.13494 | .91259 | 1.09578 | .94510 | 1.05809 | 37 |
| 24 | .85107 | 1.17500 | .88162 | 1.13428 | .91313 | 1.09514 | .94565 | 1.05747 | 36 |
| 25 | .85157 | 1.17430 | .88214 | 1.13361 | .91366 | 1.09450 | .94620 | 1.05685 | 35 |
| 26 | .85207 | 1.17361 | .88265 | 1.13295 | .91419 | 1.09386 | .94676 | 1.05624 | 34 |
| 27 | .85257 | 1.17292 | .88317 | 1.13228 | .91473 | 1.09322 | .94731 | 1.05562 | 33 |
| 28 | .85308 | 1.17223 | .88369 | 1.13162 | .91526 | 1.09258 | .94786 | 1.05501 | 32 |
| 29 | .85358 | 1.17154 | .88421 | 1.13096 | .91580 | 1.09195 | .94841 | 1.05439 | 31 |
| 30 | .85408 | 1.17085 | .88473 | 1.13029 | .91633 | 1.09131 | .94896 | 1.05378 | 30 |
| 31 | .85458 | 1.17016 | .88524 | 1.12963 | .91687 | 1.09067 | .94952 | 1.05317 | 29 |
| 32 | .85509 | 1.16947 | .88576 | 1.12897 | .91740 | 1.09003 | .95007 | 1.05255 | 28 |
| 33 | .85559 | 1.16878 | .88628 | 1.12831 | .91794 | 1.08940 | .95062 | 1.05194 | 27 |
| 34 | .85609 | 1.16809 | .88680 | 1.12765 | .91847 | 1.08876 | .95118 | 1.05133 | 26 |
| 35 | .85660 | 1.16741 | .88732 | 1.12699 | .91901 | 1.08813 | .95173 | 1.05072 | 25 |
| 36 | .85710 | 1.16672 | .88784 | 1.12633 | 91955 | 1.08749 | .95229 | 1.05010 | 24 |
| 37 | .85761 | 1.16603 | .88836 | 1.12567 | .92008 | 1.08686 | .95284 | 1.04949 | 23 |
| 38 | .85811 | 1.16535 | .88888 | 1.12501 | .92062 | 1.08622 | .95340 | 1.04888 | 22 |
| 39 | .85862 | 1.16466 | .88940 | 1.12435 | .92116 | 1.08559 | .95395 | 1.04827 | 21 |
| 40 | .85912 | 1.16398 | .88992 | 1.12369 | .92170 | 1.08496 | .95451 | 1.04766 | 20 |
| 41 | .85963 | 1.16329 | .89045 | 1.12303 | .92224 | 1.08432 | .95506 | 1.04705 | 19 |
| 42 | .86014 | 1.16261 | .89097 | 1.12238 | .92277 | 1.08369 | .95562 | 1.04644 | 18 |
| 43 | .86064 | 1.16192 | .89149 | 1.12172 | .92331 | 1.08306 | .95618 | 1.04583 | 17 |
| 44 | .86115 | 1.16124 | .89201 | 1.12106 | .92385 | 1.08243 | .95673 | 1.04522 | 16 |
| 45 | .86166 | 1.16056 | .89253 | 1.12041 | .92439 | 1.08179 | .95729 | 1.04461 | 15 |
| 46 | .86216 | 1.15987 | .89306 | 1.11975 | .92493 | 1.08116 | .95785 | 1.04401 | 14 |
| 47 | .86267 | 1.15919 | .89358 | 1.11909 | .92547 | 1.08053 | .95841 | 1.04340 | 13 |
| 48 | .86318 | 1.15851 | .89410 | 1.11844 | .92601 | 1.07990 | .95897 | 1.04279 | 12 |
| 49 | .86368 | 1.15783 | .89463 | 1 11778 | .92655 | 1.07927 | .95952 | 1.04218 | 11 |
| 50 | .86419 | 1.15715 | .89515 | 1.11713 | .92709 | 1.07864 | .96008 | 1.04158 | 10 |
| 51 | .86470 | 1.15647 | .89567 | 1.11648 | .92763 | 1.07801 | .96064 | 1.04097 | 9 |
| 52 | .86521 | 1.15579 | .89620 | 1.11582 | .92817 | 1.07738 | .96120 | 1.04036 | 8 |
| 53 | .86572 | 1.15511 | .89672 | 1.11517 | .92872 | 1.07676 | .96176 | 1 03976 | 7 |
| 54 | .86623 | 1.15443 | .89725 | 1.11452 | .92926 | 1.07613 | .96232 | 1.03915 | 6 |
| 55 | .86674 | 1.15375 | .89777 | 1.11387 | .92980 | 1.07550 | .96288 | 1.03855 | 5 |
| 56 | .86725 | 1.15308 | .89830 | 1.11321 | .93034 | 1.07487 | .96344 | 1.03794 | 4 |
| 57 | .86776 | 1.15240 | .89883 | 1.11256 | .93088 | 1.07425 | .96400 | 1.03734 | 3 |
| 58 | .86827 | 1.15172 | .89935 | 1.11191 | .93143 | 1.07362 | .96457 | 1.03674 | 2 |
| 59 | .86878 | 1.15104 | .89988 | 1.11126 | .93197 | 1.07299 | .96513 | 1.03613 | 1 |
| 60 | .86929 | 1.15037 | .90040 | 1.11061 | .93252 | 1.07237 | .96569 | 1.03553 | 0 |
| ′ | Cotang | Tang | Cotang | Tang | Cotang | Tang | Cotang | Tang | ′ |
|  | 49° |  | 48° |  | 47° |  | 46° |  |  |

| ′ | 44° | | ′ | ′ | 44° | | ′ | ′ | 44° | | ′ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tang | Cotang | | | Tang | Cotang | | | Tang | Cotang | |
| 0 | .96569 | 1.03553 | 60 | 20 | .97700 | 1.02355 | 40 | 40 | .98843 | 1.01170 | 20 |
| 1 | .96625 | 1.03493 | 59 | 21 | .97756 | 1.02295 | 39 | 41 | .98901 | 1.01112 | 19 |
| 2 | .96681 | 1.03433 | 58 | 22 | .97813 | 1.02236 | 38 | 42 | .98958 | 1.01053 | 18 |
| 3 | .96738 | 1.03372 | 57 | 23 | .97870 | 1.02176 | 37 | 43 | .99016 | 1.00994 | 17 |
| 4 | .96794 | 1.03312 | 56 | 24 | .97927 | 1.02117 | 36 | 44 | .99073 | 1.00935 | 16 |
| 5 | .96850 | 1.03252 | 55 | 25 | .97984 | 1.02057 | 35 | 45 | .99131 | 1.00876 | 15 |
| 6 | .96907 | 1.03192 | 54 | 26 | .98041 | 1.01998 | 34 | 46 | .99189 | 1.00818 | 14 |
| 7 | .96963 | 1.03132 | 53 | 27 | .98098 | 1.01939 | 33 | 47 | .99247 | 1.00759 | 13 |
| 8 | .97020 | 1.03072 | 52 | 28 | .98155 | 1.01879 | 32 | 48 | .99304 | 1.00701 | 12 |
| 9 | .97076 | 1.03012 | 51 | 29 | .98213 | 1.01820 | 31 | 49 | .99362 | 1.00642 | 11 |
| 10 | .97133 | 1.02952 | 50 | 30 | .98270 | 1.01761 | 30 | 50 | .99420 | 1.00583 | 10 |
| 11 | .97189 | 1.02892 | 49 | 31 | .98327 | 1.01702 | 29 | 51 | .99478 | 1.00525 | 9 |
| 12 | .97246 | 1.02832 | 48 | 32 | .98384 | 1.01642 | 28 | 52 | .99536 | 1.00467 | 8 |
| 13 | .97302 | 1.02772 | 47 | 33 | .98441 | 1.01583 | 27 | 53 | .99594 | 1.00408 | 7 |
| 14 | .97359 | 1.02713 | 46 | 34 | .98499 | 1.01524 | 26 | 54 | .99652 | 1.00350 | 6 |
| 15 | .97416 | 1.02653 | 45 | 35 | .98556 | 1.01465 | 25 | 55 | .99710 | 1.00291 | 5 |
| 16 | .97472 | 1.02593 | 44 | 36 | .98613 | 1.01406 | 24 | 56 | .99768 | 1.00233 | 4 |
| 17 | .97529 | 1.02533 | 43 | 37 | .98671 | 1.01347 | 23 | 57 | .99826 | 1.00175 | 3 |
| 18 | .97586 | 1.02474 | 42 | 38 | .98728 | 1.01288 | 22 | 58 | .99884 | 1.00116 | 2 |
| 19 | .97643 | 1.02414 | 41 | 39 | .98786 | 1.01229 | 21 | 59 | .99942 | 1.00058 | 1 |
| 20 | .97700 | 1.02355 | 40 | 40 | .98843 | 1.01170 | 20 | 60 | 1.00000 | 1.00000 | 0 |
| ′ | Cotang | Tang | ′ | ′ | Cotang | Tang | ′ | ′ | Cotang | Tang | ′ |
| | 45° | | | | 45° | | | | 45° | | |

| ′ | 0° | | 1° | | 2° | | 3° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .00000 | .00000 | .00015 | .00015 | .00061 | .00061 | .00137 | .00137 | 0 |
| 1 | .00000 | .00000 | .00016 | .00016 | .00062 | .00062 | .00139 | 00139 | 1 |
| 2 | .00000 | .00000 | .00016 | .00016 | .00063 | .00063 | .00140 | .00140 | 2 |
| 3 | .00000 | .00000 | .00017 | .00017 | .00064 | .00064 | .00142 | .00142 | 3 |
| 4 | .00000 | .00000 | .00017 | .00017 | .00065 | .00065 | .00143 | .00143 | 4 |
| 5 | .00000 | .00000 | .00018 | .00018 | .00066 | .00066 | .00145 | .00145 | 5 |
| 6 | .00000 | .00000 | .00018 | .00018 | .00067 | .00067 | .00146 | .00147 | 6 |
| 7 | .00000 | .00000 | .00019 | .00019 | .00068 | .00068 | .00148 | .00148 | 7 |
| 8 | .00000 | .00000 | .00020 | .00020 | .00069 | .00069 | .00150 | .00150 | 8 |
| 9 | .00000 | .00000 | .00020 | .00020 | .00070 | .00070 | .00151 | .00151 | 9 |
| 10 | .00000 | .00000 | .00021 | .00021 | .00071 | .00072 | .00153 | .00153 | 10 |
| 11 | .00001 | .00001 | .00021 | .00021 | .00073 | .00073 | .00154 | .00155 | 11 |
| 12 | .00001 | .00001 | .00022 | .00022 | .00074 | .00074 | .00156 | .00156 | 12 |
| 13 | .00001 | .00001 | .00023 | .00023 | .00075 | .00075 | .00158 | .00158 | 13 |
| 14 | .00001 | .00001 | .00023 | .00023 | .00076 | .00076 | .00159 | .00159 | 14 |
| 15 | .00001 | .00001 | .00024 | .00024 | .00077 | .00077 | .00161 | .00161 | 15 |
| 16 | .00001 | .00001 | .00024 | .00024 | .00078 | .00078 | .00162 | .00163 | 16 |
| 17 | .00001 | .00001 | .00025 | .00025 | .00079 | .00079 | .00164 | .00164 | 17 |
| 18 | .00001 | .00001 | .00026 | .00026 | .00081 | .00081 | .00166 | .00166 | 18 |
| 19 | .00002 | .00002 | .00026 | .00026 | .00082 | .00082 | .00168 | .00168 | 19 |
| 20 | .00002 | .00002 | .00027 | .00027 | .00083 | .00083 | .00169 | .00169 | 20 |
| 21 | .00002 | .00002 | .00028 | .00028 | .00084 | .00084 | .00171 | .00171 | 21 |
| 22 | .00002 | .00002 | .00028 | .00028 | .00085 | .00085 | .00173 | .00173 | 22 |
| 23 | .00002 | .00002 | .00029 | .00029 | .00087 | .00087 | .00174 | .00175 | 23 |
| 24 | .00002 | .00002 | .00030 | .00030 | .00088 | .00088 | .00176 | .00176 | 24 |
| 25 | .00003 | .00003 | .00031 | .00031 | .00089 | .00089 | .00178 | .00178 | 25 |
| 26 | .00003 | .00003 | .00031 | .00031 | .00090 | .00090 | .00179 | .00180 | 26 |
| 27 | .00003 | .00003 | .00032 | .00032 | .00091 | .00091 | .00181 | .00182 | 27 |
| 28 | .00003 | .00003 | .00033 | .00033 | .00093 | .00093 | .00183 | .00183 | 28 |
| 29 | .00004 | .00004 | .00034 | .00034 | .00094 | .00094 | .00185 | .00185 | 29 |
| 30 | .00004 | .00004 | .00034 | .00034 | .00095 | .00095 | .00187 | .00187 | 30 |
| 31 | .00004 | .00004 | .00035 | .00035 | .00096 | .00097 | .00188 | .00189 | 31 |
| 32 | .00004 | .00004 | .00036 | .00036 | .00098 | .00098 | .00190 | .00190 | 32 |
| 33 | .00005 | .00005 | .00037 | .00037 | .00099 | .00099 | .00192 | .00192 | 33 |
| 34 | .00005 | .00005 | .00037 | .00037 | .00100 | .00100 | .00194 | .00194 | 34 |
| 35 | .00005 | .00005 | .00038 | .00038 | .00102 | .00102 | .00196 | .00196 | 35 |
| 36 | .00005 | .00005 | .00039 | .00039 | .00103 | .00103 | .00197 | .00198 | 36 |
| 37 | .00006 | .00006 | .00040 | .00040 | .00104 | .00104 | .00199 | .00200 | 37 |
| 38 | .00006 | .00006 | .00041 | .00041 | .00106 | .00106 | .00201 | .00201 | 38 |
| 39 | .00006 | .00006 | .00041 | .00041 | .00107 | .00107 | .00203 | .00203 | 39 |
| 40 | .00007 | .00007 | .00042 | .00042 | .00108 | .00108 | .00205 | .00205 | 40 |
| 41 | .00007 | .00007 | .00043 | .00043 | .00110 | .00110 | .00207 | .00207 | 41 |
| 42 | .00007 | .00007 | .00044 | .00044 | .00111 | .00111 | .00208 | .00209 | 42 |
| 43 | .00008 | .00008 | .00045 | .00045 | .00112 | .00113 | .00210 | .00211 | 43 |
| 44 | .00008 | .00008 | .00046 | .00046 | .00114 | .00114 | .00212 | .00213 | 44 |
| 45 | .00009 | .00009 | .00047 | .00047 | .00115 | .00115 | .00214 | .00215 | 45 |
| 46 | .00009 | .00009 | .00048 | .00048 | .00117 | .00117 | .00216 | .00216 | 46 |
| 47 | .00009 | .00009 | .00048 | .00048 | .00118 | .00118 | .00218 | .00218 | 47 |
| 48 | .00010 | .00010 | .00049 | .00049 | .00119 | .00120 | .00220 | .00220 | 48 |
| 49 | .00010 | .00010 | .00050 | .00050 | .00121 | .00121 | .00222 | .00222 | 49 |
| 50 | .00011 | .00011 | .00051 | .00051 | .00122 | .00122 | .00224 | .00224 | 50 |
| 51 | .00011 | .00011 | .00052 | .00052 | .00124 | .00124 | .00226 | .00226 | 51 |
| 52 | .00011 | .00011 | .00053 | .00053 | .00125 | .00125 | .00228 | .00228 | 52 |
| 53 | .00012 | .00012 | .00054 | .00054 | .00127 | .00127 | .00230 | .00230 | 53 |
| 54 | .00012 | .00012 | .00055 | .00055 | .00128 | .00128 | .00232 | .00232 | 54 |
| 55 | .00013 | .00013 | .00056 | .00056 | .00130 | .00130 | .00234 | .00234 | 55 |
| 56 | .00013 | .00013 | .00057 | .00057 | .00131 | .00131 | .00236 | .00236 | 56 |
| 57 | .00014 | .00014 | .00058 | .00058 | .00133 | .00133 | .00238 | .00238 | 57 |
| 58 | .00014 | .00014 | .00059 | .00059 | .00134 | .00134 | .00240 | .00240 | 58 |
| 59 | .00015 | .00015 | .00060 | .00060 | .00136 | .00136 | .00242 | .00242 | 59 |
| 60 | .00015 | .00015 | .00061 | .00061 | .00137 | .00137 | .00244 | .00244 | 60 |

| ′ | 4° | | 5° | | 6° | | 7° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .00244 | .00244 | .00381 | .00382 | .00548 | .00551 | .00745 | .00751 | 0 |
| 1 | .00246 | .00246 | .00383 | .00385 | .00551 | .00554 | .00749 | .00755 | 1 |
| 2 | .00248 | .00248 | .00386 | .00387 | .00554 | .00557 | .00752 | .00758 | 2 |
| 3 | .00250 | .00250 | .00388 | .00390 | .00557 | .00560 | .00756 | .00762 | 3 |
| 4 | .00252 | .00252 | .00391 | .00392 | .00560 | .00563 | .00760 | .00765 | 4 |
| 5 | .00254 | .00254 | .00393 | .00395 | .00563 | .00566 | .00763 | .00769 | 5 |
| 6 | .00256 | .00257 | .00396 | .00397 | .00566 | .00569 | .00767 | .00773 | 6 |
| 7 | .00258 | .00259 | .00398 | .00400 | .00569 | .00573 | .00770 | .00776 | 7 |
| 8 | .00260 | .00261 | .00401 | .00403 | .00572 | .00576 | .00774 | .00780 | 8 |
| 9 | .00262 | .00263 | .00404 | .00405 | .00576 | .00579 | .00778 | .00784 | 9 |
| 10 | .00264 | .00265 | .00406 | .00408 | .00579 | .00582 | .00781 | .00787 | 10 |
| 11 | .00266 | .00267 | .00409 | .00411 | 00582 | .00585 | .00785 | .00791 | 11 |
| 12 | .00269 | .00269 | .00412 | .00413 | .00585 | .00588 | .00789 | .00795 | 12 |
| 13 | .00271 | .00271 | .00414 | .00416 | .00588 | .00592 | .00792 | .00799 | 13 |
| 14 | .00273 | .00274 | .00417 | .00419 | .00591 | .00595 | 00796 | .00802 | 14 |
| 15 | .00275 | .00276 | .00420 | .00421 | 00594 | .00598 | .00800 | .00806 | 15 |
| 16 | .00277 | .00278 | .00422 | .00424 | .00598 | .00601 | .00803 | .00810 | 16 |
| 17 | .00279 | .00280 | .00425 | .00427 | .00601 | .00604 | .00807 | .00813 | 17 |
| 18 | .00281 | .00282 | .00428 | .00429 | 00604 | .00608 | .00811 | .00817 | 18 |
| 19 | .00284 | .00284 | .00430 | .00432 | .00607 | .00611 | .00814 | .00821 | 19 |
| 20 | .00286 | .00287 | .00433 | .00435 | .00610 | .00614 | .00818 | .00825 | 20 |
| 21 | .00288 | .00289 | .00436 | .00438 | .00614 | .00617 | .00822 | .00828 | 21 |
| 22 | .00290 | .00291 | .00438 | .00440 | .00617 | .00621 | .00825 | .00832 | 22 |
| 23 | .00293 | .00293 | .00441 | .00443 | .00620 | .00624 | .00829 | .00836 | 23 |
| 24 | .00295 | .00296 | .00444 | .00446 | .00623 | .00627 | .00833 | .00840 | 24 |
| 25 | .00297 | .00298 | .00447 | .00449 | .00626 | .00630 | .00837 | .00844 | 25 |
| 26 | .00299 | .00300 | .00449 | .00451 | .00630 | .00634 | .00840 | .00848 | 26 |
| 27 | .00301 | .00302 | .00452 | .00454 | .00633 | .00637 | .00844 | .00851 | 27 |
| 28 | .00304 | .00305 | .00455 | .00457 | .00636 | .00640 | .00848 | .00855 | 28 |
| 29 | .00306 | .00307 | .00458 | .00460 | .00640 | .00644 | .00852 | .00859 | 29 |
| 30 | .00308 | .00309 | .00460 | .00463 | .00643 | .00647 | .00856 | .00863 | 30 |
| 31 | .00311 | .00312 | .00463 | .00465 | .00646 | .00650 | .00859 | .00867 | 31 |
| 32 | .00313 | .00314 | .00466 | .00468 | .00649 | .00654 | .00863 | .00871 | 32 |
| 33 | .00315 | .00316 | .00469 | .00471 | .00653 | .00657 | .00867 | .00875 | 33 |
| 34 | .00317 | .00318 | .00472 | .00474 | .00656 | .00660 | .00871 | .00878 | 34 |
| 35 | .00320 | .00321 | .00474 | .00477 | .00659 | .00664 | .00875 | .00882 | 35 |
| 36 | .00322 | .00323 | .00477 | .00480 | .00663 | .00667 | .00878 | .00886 | 36 |
| 37 | .00324 | .00326 | .00480 | .00482 | .00666 | .00671 | .00882 | .00890 | 37 |
| 38 | .00327 | .00328 | .00483 | .00485 | .00669 | .00674 | .00886 | .00894 | 38 |
| 39 | .00329 | .00330 | .00486 | .00488 | .00673 | .00677 | .00890 | .00898 | 39 |
| 40 | .00332 | .00333 | .00489 | .00491 | .00676 | .00681 | .00894 | .00902 | 40 |
| 41 | .00334 | .00335 | .00492 | .00494 | .00680 | .00684 | .00898 | .00906 | 41 |
| 42 | .00336 | .00337 | .00494 | .00497 | .00683 | .00688 | .00902 | .00910 | 42 |
| 43 | .00339 | .00340 | .00497 | .00500 | .00686 | .00691 | .00906 | .00914 | 43 |
| 44 | .00341 | .00342 | .00500 | .00503 | 00690 | .00695 | .00909 | .00918 | 44 |
| 45 | .00343 | .00345 | .00503 | .00506 | .00693 | .00698 | 00913 | .00922 | 45 |
| 46 | .00346 | .00347 | .00506 | .00509 | .00697 | .00701 | 00917 | .00926 | 46 |
| 47 | .00348 | .00350 | .00509 | .00512 | .00700 | .00705 | 00921 | .00930 | 47 |
| 48 | .00351 | .00352 | .00512 | .00515 | .00703 | .00708 | .00925 | .00934 | 48 |
| 49 | .00353 | .00354 | .00515 | .00518 | .00707 | .00712 | 00929 | .00938 | 49 |
| 50 | .00356 | .00357 | .00518 | .00521 | .00710 | .00715 | .00933 | .00942 | 50 |
| 51 | .00358 | .00359 | .00521 | .00524 | .00714 | .00719 | .00937 | .00946 | 51 |
| 52 | .00361 | .00362 | .00524 | .00527 | .00717 | .00722 | .00941 | .00950 | 52 |
| 53 | .00363 | .00364 | .00527 | .00530 | .00721 | .00726 | .00945 | .00954 | 53 |
| 54 | .00365 | .00367 | .00530 | .00533 | .00724 | .00730 | .00949 | .00958 | 54 |
| 55 | .00368 | .00369 | .00533 | .00536 | .00728 | .00735 | .00953 | .00962 | 55 |
| 56 | .00370 | .00372 | .00536 | .00539 | .00731 | .00737 | .00957 | .00966 | 56 |
| 57 | .00373 | .00374 | .00539 | .00542 | .00735 | .00740 | .00961 | .00970 | 57 |
| 58 | .00375 | .00377 | .00542 | .00545 | .00738 | .00744 | .00965 | .00975 | 58 |
| 59 | .00378 | .00379 | .00545 | .00548 | .00742 | .00747 | .00969 | .00979 | 59 |
| 60 | .00381 | .00382 | .00548 | .00551 | .00745 | .00751 | .00973 | .00983 | 60 |

| ′ | 8° |  | 9° |  | 10° |  | 11° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .00973 | .00983 | .01231 | .01247 | .01519 | .01543 | .01837 | .01872 | 0 |
| 1 | .00977 | .00987 | .01236 | .01251 | .01524 | .01548 | .01843 | .01877 | 1 |
| 2 | .00981 | .00991 | .01240 | .01256 | .01529 | .01553 | .01848 | .01883 | 2 |
| 3 | .00985 | .00995 | .01245 | .01261 | .01534 | .01558 | .01854 | .01889 | 3 |
| 4 | .00989 | .00999 | .01249 | .01265 | .01540 | .01564 | .01860 | .01895 | 4 |
| 5 | .00994 | .01004 | .01254 | .01270 | .01545 | .01569 | .01865 | .01901 | 5 |
| 6 | .00998 | .01008 | .01259 | .01275 | .01550 | .01574 | .01871 | .01906 | 6 |
| 7 | .01002 | .01012 | .01263 | .01279 | .01555 | .01579 | .01876 | .01912 | 7 |
| 8 | .01006 | .01016 | .01268 | .01284 | .01560 | .01585 | .01882 | .01918 | 8 |
| 9 | .01010 | .01020 | .01272 | .01289 | .01565 | .01590 | .01888 | .01924 | 9 |
| 10 | .01014 | .01024 | .01277 | .01294 | .01570 | .01595 | .01893 | .01930 | 10 |
| 11 | .01018 | .01029 | .01282 | .01298 | .01575 | .01601 | .01899 | .01936 | 11 |
| 12 | .01022 | .01033 | .01286 | .01303 | .01580 | .01606 | .01904 | .01941 | 12 |
| 13 | .01027 | .01037 | .01291 | .01308 | .01586 | .01611 | .01910 | .01947 | 13 |
| 14 | .01031 | .01041 | .01296 | .01313 | .01591 | .01616 | .01916 | .01953 | 14 |
| 15 | .01035 | .01046 | .01300 | .01318 | .01596 | .01622 | .01921 | .01959 | 15 |
| 16 | .01039 | .01050 | .01305 | .01322 | .01601 | .01627 | .01927 | .01965 | 16 |
| 17 | .01043 | .01054 | .01310 | .01327 | .01606 | .01633 | .01933 | .01971 | 17 |
| 18 | .01047 | .01059 | .01314 | .01332 | .01612 | .01638 | .01939 | .01977 | 18 |
| 19 | .01052 | .01063 | .01319 | .01337 | .01617 | .01643 | .01944 | .01983 | 19 |
| 20 | .01056 | .01067 | .01324 | .01342 | .01622 | .01649 | .01950 | .01989 | 20 |
| 21 | .01060 | .01071 | .01329 | .01346 | .01627 | .01654 | .01956 | .01995 | 21 |
| 22 | .01064 | .01076 | .01333 | .01351 | .01632 | .01659 | .01961 | .02001 | 22 |
| 23 | .01069 | .01080 | .01338 | .01356 | .01638 | .01665 | .01967 | .02007 | 23 |
| 24 | .01073 | .01084 | .01343 | .01361 | .01643 | .01670 | .01973 | .02013 | 24 |
| 25 | .01077 | .01089 | .01348 | .01366 | .01648 | .01676 | .01979 | .02019 | 25 |
| 26 | .01081 | .01093 | .01352 | .01371 | .01653 | .01681 | .01984 | .02025 | 26 |
| 27 | .01086 | .01097 | .01357 | .01376 | .01659 | .01687 | .01990 | .02031 | 27 |
| 28 | .01090 | .01102 | .01362 | .01381 | .01664 | .01692 | .01996 | .02037 | 28 |
| 29 | .01094 | .01106 | .01367 | .01386 | .01669 | .01698 | .02002 | .02043 | 29 |
| 30 | .01098 | .01111 | .01371 | .01391 | .01675 | .01703 | .02008 | .02049 | 30 |
| 31 | .01103 | .01115 | .01376 | .01395 | .01680 | .01709 | .02013 | .02055 | 31 |
| 32 | .01107 | .01119 | .01381 | .01400 | .01685 | .01714 | .02019 | .02061 | 32 |
| 33 | .01111 | .01124 | .01386 | .01405 | .01690 | .01720 | .02025 | .02067 | 33 |
| 34 | .01116 | .01128 | .01391 | .01410 | .01696 | .01725 | .02031 | .02073 | 34 |
| 35 | .01120 | .01133 | .01396 | .01415 | .01701 | .01731 | .02037 | .02079 | 35 |
| 36 | .01124 | .01137 | .01400 | .01420 | .01706 | .01736 | .02042 | .02085 | 36 |
| 37 | .01129 | .01142 | .01405 | .01425 | .01712 | .01742 | .02048 | .02091 | 37 |
| 38 | .01133 | .01146 | .01410 | .01430 | .01717 | .01747 | .02054 | .02097 | 38 |
| 39 | .01137 | .01151 | .01415 | .01435 | .01723 | .01753 | .02060 | .02103 | 39 |
| 40 | .01142 | .01155 | .01420 | .01440 | .01728 | .01758 | .02066 | .02110 | 40 |
| 41 | .01146 | .01160 | .01425 | .01445 | .01733 | .01764 | .02072 | .02116 | 41 |
| 42 | .01151 | .01164 | .01430 | .01450 | .01739 | .01769 | .02078 | .02122 | 42 |
| 43 | .01155 | .01169 | .01435 | .01455 | .01744 | .01775 | .02084 | .02128 | 43 |
| 44 | .01159 | .01173 | .01439 | .01461 | .01750 | .01781 | .02090 | .02134 | 44 |
| 45 | .01164 | .01178 | .01444 | .01466 | .01755 | .01786 | .02095 | .02140 | 45 |
| 46 | .01168 | .01182 | .01449 | .01471 | .01760 | .01792 | .02101 | .02146 | 46 |
| 47 | .01173 | .01187 | .01454 | .01476 | .01766 | .01798 | .02107 | .02153 | 47 |
| 48 | .01177 | .01191 | .01459 | .01481 | .01771 | .01803 | .02113 | .02159 | 48 |
| 49 | .01182 | .01196 | .01464 | .01486 | .01777 | .01809 | .02119 | .02165 | 49 |
| 50 | .01186 | .01200 | .01469 | .01491 | .01782 | .01815 | .02125 | .02171 | 50 |
| 51 | .01191 | .01205 | .01474 | .01496 | .01788 | .01820 | .02131 | .02178 | 51 |
| 52 | .01195 | .01209 | .01479 | .01501 | .01793 | .01826 | .02137 | .02184 | 52 |
| 53 | .01200 | .01214 | .01484 | .01506 | .01799 | .01832 | .02143 | .02190 | 53 |
| 54 | .01204 | .01219 | .01489 | .01512 | .01804 | .01837 | .02149 | .02196 | 54 |
| 55 | .01209 | .01223 | .01494 | .01517 | .01810 | .01843 | .02155 | .02203 | 55 |
| 56 | .01213 | .01228 | .01499 | .01522 | .01815 | .01849 | .02161 | .02209 | 56 |
| 57 | .01218 | .01233 | .01504 | .01527 | .01821 | .01854 | .02167 | .02215 | 57 |
| 58 | .01222 | .01237 | .01509 | .01532 | .01826 | .01860 | .02173 | .02221 | 58 |
| 59 | .01227 | .01242 | .01514 | .01537 | .01832 | .01866 | .02179 | .02228 | 59 |
| 60 | .01231 | .01247 | .01519 | .01543 | .01837 | .01872 | .02185 | .02234 | 60 |

| ′ | 12° | | 13° | | 14° | | 15° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .02185 | .02234 | .02563 | .02630 | .02970 | .03061 | .03407 | .03528 | 0 |
| 1 | .02191 | .02240 | .02570 | .02637 | .02977 | .03069 | .03415 | .03536 | 1 |
| 2 | .02197 | .02247 | .02576 | .02644 | .02985 | .03076 | .03422 | .03544 | 2 |
| 3 | .02203 | .02253 | .02583 | .02651 | .02992 | .03084 | .03430 | .03552 | 3 |
| 4 | .02210 | .02259 | .02589 | .02658 | .02999 | .03091 | .03438 | .03560 | 4 |
| 5 | .02216 | .02266 | .02596 | .02665 | .03006 | .03099 | .03445 | .03568 | 5 |
| 6 | .02222 | .02272 | .02602 | .02672 | .03013 | .03106 | .03453 | .03576 | 6 |
| 7 | .02228 | .02279 | .02609 | .02679 | .03020 | .03114 | .03460 | .03584 | 7 |
| 8 | .02234 | .02285 | .02616 | .02686 | .03027 | .03121 | .03468 | .03592 | 8 |
| 9 | .02240 | .02291 | .02622 | .02693 | .03034 | .03129 | .03476 | .03601 | 9 |
| 10 | .02246 | .02298 | .02629 | .02700 | .03041 | .03137 | .03483 | .03609 | 10 |
| 11 | .02252 | .02304 | .02635 | .02707 | .03048 | .03144 | .03491 | .03617 | 11 |
| 12 | .02258 | .02311 | .02642 | .02714 | .03055 | .03152 | .03498 | .03625 | 12 |
| 13 | .02265 | .02317 | .02649 | .02721 | .03063 | .03159 | .03506 | 03633 | 13 |
| 14 | .02271 | .02323 | .02655 | .02728 | .03070 | .03167 | .03514 | .03642 | 14 |
| 15 | .02277 | .02330 | .02662 | .02735 | .03077 | .03175 | .03521 | .03650 | 15 |
| 16 | .02283 | .02336 | .02669 | .02742 | .03084 | .03182 | .03529 | .03658 | 16 |
| 17 | .02289 | .02343 | .02675 | .02749 | .03091 | .03190 | .03537 | .03666 | 17 |
| 18 | .02295 | .02349 | .02682 | .02756 | .03098 | .03198 | .03544 | .03674 | 18 |
| 19 | .02302 | .02356 | .02689 | .02763 | .03106 | .03205 | .03552 | .03683 | 19 |
| 20 | .02308 | .02362 | .02696 | .02770 | .03113 | .03213 | .03560 | .03691 | 20 |
| 21 | .02314 | .02369 | .02702 | .02777 | .03120 | .03221 | .03567 | .03699 | 21 |
| 22 | .02320 | .02375 | .02709 | .02784 | .03127 | .03228 | .03575 | .03708 | 22 |
| 23 | .02327 | .02382 | .02716 | .02791 | .03134 | .03236 | .03583 | .03716 | 23 |
| 24 | .02333 | .02388 | .02722 | .02799 | .03142 | .03244 | .03590 | .03724 | 24 |
| 25 | .02339 | .02395 | .02729 | .02806 | .03149 | .03251 | .03598 | .03732 | 25 |
| 26 | .02345 | .02402 | .02736 | .02813 | .03156 | .03259 | .03606 | .03741 | 26 |
| 27 | .02352 | .02408 | .02743 | .02820 | .03163 | .03267 | .03614 | .03749 | 27 |
| 28 | .02358 | .02415 | .02749 | .02827 | .03171 | .03275 | .03621 | .03758 | 28 |
| 29 | .02364 | .02421 | .02756 | .02834 | .03178 | .03282 | .03629 | .03766 | 29 |
| 30 | .02370 | .02428 | .02763 | .02842 | .03185 | .03290 | .03637 | .03774 | 30 |
| 31 | .02377 | .02435 | .02770 | .02849 | .03193 | .03298 | .03645 | .03783 | 31 |
| 32 | .02383 | .02441 | .02777 | .02856 | .03200 | .03306 | .03653 | .03791 | 32 |
| 33 | .02389 | .02448 | .02783 | .02863 | .03207 | .03313 | .03660 | .03799 | 33 |
| 34 | .02396 | .02454 | .02790 | .02870 | .03214 | .03321 | .03668 | .03808 | 34 |
| 35 | .02402 | .02461 | .02797 | .02878 | .03222 | .03329 | .03676 | .03816 | 35 |
| 36 | .02408 | .02468 | .02804 | .02885 | .03229 | .03337 | .03684 | .03825 | 36 |
| 37 | .02415 | .02474 | .02811 | .02892 | .03236 | .03345 | .03692 | .03833 | 37 |
| 38 | .02421 | .02481 | .02818 | .02899 | .03244 | .03353 | .03699 | .03842 | 38 |
| 39 | .02427 | .02488 | .02824 | .02907 | .03251 | .03360 | .03707 | .03850 | 39 |
| 40 | .02434 | .02494 | .02831 | .02914 | .03258 | .03368 | .03715 | .03858 | 40 |
| 41 | .02440 | .02501 | .02838 | .02921 | .03266 | .03376 | .03723 | .03867 | 41 |
| 42 | .02447 | .02508 | .02845 | .02928 | .03273 | .03384 | .03731 | .03875 | 42 |
| 43 | .02453 | .02515 | .02852 | .02936 | .03281 | .03392 | .03739 | .03884 | 43 |
| 44 | .02459 | .02521 | .02859 | .02943 | .03288 | .03400 | .03747 | .03892 | 44 |
| 45 | .02466 | .02528 | .02866 | .02950 | .03295 | .03408 | .03754 | .03901 | 45 |
| 46 | .02472 | .02535 | .02873 | .02958 | .03303 | .03416 | .03762 | .03909 | 46 |
| 47 | .02479 | .02542 | .02880 | .02965 | .03310 | .03424 | .03770 | .03918 | 47 |
| 48 | .02485 | .02548 | .02887 | .02972 | .03318 | .03432 | .03778 | .03927 | 48 |
| 49 | .02492 | .02555 | .02894 | .02980 | .03325 | .03439 | .03786 | .03935 | 49 |
| 50 | .02498 | .02562 | .02900 | .02987 | .03333 | .03447 | .03794 | .03944 | 50 |
| 51 | .02504 | .02569 | .02907 | .02994 | .03340 | .03455 | .03802 | .03952 | 51 |
| 52 | .02511 | .02576 | .02914 | .03002 | .03347 | .03463 | .03810 | .03961 | 52 |
| 53 | .02517 | .02582 | .02921 | .03009 | .03355 | .03471 | .03818 | .03969 | 53 |
| 54 | .02524 | .02589 | .02928 | .03017 | .03362 | .03479 | .03826 | .03978 | 54 |
| 55 | .02530 | .02596 | .02935 | .03024 | .03370 | .03487 | .03834 | .03987 | 55 |
| 56 | .02537 | .02603 | .02942 | .03032 | .03377 | .03495 | .03842 | .03995 | 56 |
| 57 | .02543 | .02610 | .02949 | .03039 | .03385 | .03503 | .03850 | .04004 | 57 |
| 58 | .02550 | .02617 | .02956 | .03046 | .03392 | .03512 | .03858 | .04013 | 58 |
| 59 | .02556 | .02624 | .02963 | .03054 | .03400 | .03520 | .03866 | .04021 | 59 |
| 60 | .02563 | .02630 | .02970 | .03061 | .03407 | .03528 | .03874 | .04030 | 60 |

| ′ | 16° |  | 17° |  | 18° |  | 19° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .03874 | .04030 | .04370 | .04569 | .04894 | .05146 | .05448 | .05762 | 0 |
| 1 | .03882 | .04039 | .04378 | .04578 | .04903 | .05156 | .05458 | .05773 | 1 |
| 2 | .03890 | .04047 | .04387 | .04588 | .04912 | .05166 | .05467 | .05783 | 2 |
| 3 | .03898 | .04056 | .04395 | .04597 | .04921 | .05176 | .05477 | .05794 | 3 |
| 4 | .03906 | .04065 | .04404 | .04606 | .04930 | .05186 | .05486 | .05805 | 4 |
| 5 | .03914 | .04073 | .04412 | .04616 | .04939 | .05196 | .05496 | .05815 | 5 |
| 6 | .03922 | .04082 | .04421 | .04625 | .04948 | .05206 | .05505 | .05826 | 6 |
| 7 | .03930 | .04091 | .04429 | .04635 | .04957 | .05216 | .05515 | .05836 | 7 |
| 8 | .03938 | .04100 | .04438 | .04644 | .04967 | .05226 | .05524 | .05847 | 8 |
| 9 | .03946 | .04108 | .04446 | .04653 | .04976 | .05236 | .05534 | .05858 | 9 |
| 10 | .03954 | .04117 | .04455 | .04663 | .04985 | .05246 | .05543 | .05869 | 10 |
| 11 | .03963 | .04126 | .04464 | .04672 | .04994 | .05256 | .05553 | .05879 | 11 |
| 12 | .03971 | .04135 | .04472 | .04682 | .05003 | .05266 | .05562 | .05890 | 12 |
| 13 | .03979 | .04144 | .04481 | .04691 | .05012 | .05276 | .05572 | .05901 | 13 |
| 14 | .03987 | .04152 | .04489 | .04700 | .05021 | .05286 | .05582 | .05911 | 14 |
| 15 | .03995 | .04161 | .04498 | .04710 | .05030 | .05297 | .05591 | .05922 | 15 |
| 16 | .04003 | .04170 | .04507 | .04719 | .05039 | .05307 | .05601 | .05933 | 16 |
| 17 | .04011 | .04179 | .04515 | .04729 | .05048 | .05317 | .05610 | .05944 | 17 |
| 18 | .04019 | .04188 | .04524 | .04738 | .05057 | .05327 | .05620 | .05955 | 18 |
| 19 | .04028 | .04197 | .04533 | .04748 | .05067 | .05337 | .05630 | .05965 | 19 |
| 20 | .04036 | .04206 | .04541 | .04757 | .05076 | .05347 | .05639 | .05976 | 20 |
| 21 | .04044 | .04214 | .04550 | .04767 | .05085 | .05357 | .05649 | .05987 | 21 |
| 22 | .04052 | .04223 | .04559 | .04776 | .05094 | .05367 | .05658 | .05998 | 22 |
| 23 | .04060 | .04232 | .04567 | .04786 | .05103 | .05378 | .05668 | .06009 | 23 |
| 24 | .04069 | .04241 | .04576 | .04795 | .05112 | .05388 | .05678 | .06020 | 24 |
| 25 | .04077 | .04250 | .04585 | .04805 | .05122 | .05398 | .05687 | .06030 | 25 |
| 26 | .04085 | .04259 | .04593 | .04815 | .05131 | .05408 | .05697 | .06041 | 26 |
| 27 | .04093 | .04268 | .04602 | .04824 | .05140 | .05418 | .05707 | .06052 | 27 |
| 28 | .04102 | .04277 | .04611 | .04834 | .05149 | .05429 | .05716 | .06063 | 28 |
| 29 | .04110 | .04286 | .04620 | .04843 | .05158 | .05439 | .05726 | .06074 | 29 |
| 30 | .04118 | .04295 | .04628 | .04853 | .05168 | .05449 | .05736 | .06085 | 30 |
| 31 | .04126 | .04304 | .04637 | .04863 | .05177 | .05460 | .05746 | .06096 | 31 |
| 32 | .04135 | .04313 | .04646 | .04872 | .05186 | .05470 | .05755 | .06107 | 32 |
| 33 | .04143 | .04322 | .04655 | .04882 | .05195 | .05480 | .05765 | .06118 | 33 |
| 34 | .04151 | .04331 | .04663 | .04891 | .05205 | .05490 | .05775 | .06129 | 34 |
| 35 | .04159 | .04340 | .04672 | .04901 | .05214 | .05501 | .05785 | .06140 | 35 |
| 36 | .04168 | .04349 | .04681 | .04911 | .05223 | .05511 | .05794 | .06151 | 36 |
| 37 | .04176 | .04358 | .04690 | .04920 | .05232 | .05521 | .05804 | .06162 | 37 |
| 38 | .04184 | .04367 | .04699 | .04930 | .05242 | .05532 | .05814 | .06173 | 38 |
| 39 | .04193 | .04376 | .04707 | .04940 | .05251 | .05542 | .05824 | .06184 | 39 |
| 40 | .04201 | .04385 | .04716 | .04950 | .05260 | .05552 | .05833 | .06195 | 40 |
| 41 | .04209 | .04394 | .04725 | .04959 | .05270 | .05563 | .05843 | .06206 | 41 |
| 42 | .04218 | .04403 | .04734 | .04969 | .05279 | .05573 | .05853 | .06217 | 42 |
| 43 | .04226 | .04413 | .04743 | .04979 | .05288 | .05584 | .05863 | .06228 | 43 |
| 44 | .04234 | .04422 | .04752 | .04989 | .05298 | .05594 | .05873 | .06239 | 44 |
| 45 | .04243 | .04431 | .04760 | .04998 | .05307 | .05604 | .05882 | .06250 | 45 |
| 46 | 04251 | .04440 | .04769 | .05008 | .05316 | .05615 | .05892 | .06261 | 46 |
| 47 | .04260 | .04449 | .04778 | .05018 | .05326 | .05625 | .05902 | .06272 | 47 |
| 48 | .04268 | .04458 | .04787 | .05028 | .05335 | .05636 | .05912 | .06283 | 48 |
| 49 | .04276 | .04468 | .04796 | .05038 | .05344 | .05646 | .05922 | .06295 | 49 |
| 50 | .04285 | .04477 | .04805 | .05047 | .05354 | .05657 | .05932 | .06306 | 50 |
| 51 | .04293 | .04486 | .04814 | .05057 | .05363 | .05667 | .05942 | .06317 | 51 |
| 52 | .04302 | .04495 | .04823 | .05067 | .05373 | .05678 | .05951 | .06328 | 52 |
| 53 | .04310 | .04504 | .04832 | .05077 | .05382 | .05688 | .05961 | .06339 | 53 |
| 54 | .04319 | .04514 | .04841 | .05087 | .05391 | .05699 | .05971 | .06350 | 54 |
| 55 | .04327 | .04523 | .04850 | .05097 | .05401 | .05709 | .05981 | .06362 | 55 |
| 56 | .04336 | .04532 | .04858 | .05107 | .05410 | .05720 | .05991 | .06373 | 56 |
| 57 | .04344 | .04541 | .04867 | .05116 | .05420 | .05730 | .06001 | .06384 | 57 |
| 58 | .04353 | .04551 | .04876 | .05126 | .05429 | .05741 | .06011 | .06395 | 58 |
| 59 | .04361 | .04560 | .04885 | .05136 | .05439 | .05751 | .06021 | .06407 | 59 |
| 60 | .04370 | .04569 | .04894 | 05146 | .05448 | .05762 | .06031 | .06418 | 60 |

| ′ | 20° |  | 21° |  | 22° |  | 23° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .06031 | .06418 | .06642 | .07115 | .07282 | .07853 | .07950 | .08636 | 0 |
| 1 | .06041 | .06429 | .06652 | .07126 | .07293 | .07866 | .07961 | .08649 | 1 |
| 2 | .06051 | .06440 | .06663 | .07138 | .07303 | .07879 | .07972 | .08663 | 2 |
| 3 | .06061 | .06452 | .06673 | .07150 | .07314 | .07892 | .07984 | .08676 | 3 |
| 4 | .06071 | .06463 | .06684 | .07162 | .07325 | .07904 | .07995 | .08690 | 4 |
| 5 | .06081 | .06474 | .06694 | .07174 | .07336 | .07917 | .08006 | .08703 | 5 |
| 6 | .06091 | .06486 | .06705 | .07186 | .07347 | .07930 | .08018 | .08717 | 6 |
| 7 | .06101 | .06497 | .06715 | .07199 | .07358 | 07943 | .08029 | .08730 | 7 |
| 8 | .06111 | .06508 | .06726 | .07211 | .07369 | .07955 | .08041 | .08714 | 8 |
| 9 | .06121 | .06520 | .06736 | .07223 | .07380 | .07968 | .08052 | .08757 | 9 |
| 10 | .06131 | .06531 | .06747 | .07235 | .07391 | .07981 | .08064 | .08771 | 10 |
| 11 | .06141 | .06542 | .06757 | .07247 | .07402 | .07994 | .08075 | .08784 | 11 |
| 12 | .06151 | .06554 | .06768 | .07259 | .07413 | .08006 | .08086 | .08798 | 12 |
| 13 | .06161 | .06565 | .06778 | .07271 | .07424 | .08019 | .08098 | .08811 | 13 |
| 14 | .06171 | .06577 | .06789 | .07283 | .07435 | .08032 | .08109 | .08825 | 14 |
| 15 | .06181 | .06588 | .06799 | .07295 | .07446 | .08045 | .08121 | .08839 | 15 |
| 16 | .06191 | .06600 | .06810 | .07307 | .07457 | .08058 | .08132 | .08852 | 16 |
| 17 | .06201 | .06611 | .06820 | .07320 | .07468 | .08071 | .08144 | .08866 | 17 |
| 18 | .06211 | .06622 | .06831 | .07332 | .07479 | .08084 | .08155 | .08880 | 18 |
| 19 | .06221 | .06634 | .06841 | .07344 | .07490 | .08097 | .08167 | .08893 | 19 |
| 20 | .06231 | .06645 | .06852 | .07356 | .07501 | .08109 | .08178 | .08907 | 20 |
| 21 | .06241 | .06657 | .06863 | .07368 | .07512 | .08122 | .08190 | .08921 | 21 |
| 22 | .06252 | .06668 | .06873 | .07380 | .07523 | .08135 | .08201 | .08934 | 22 |
| 23 | .06262 | .06680 | .06884 | .07393 | .07534 | .08148 | .08213 | .08948 | 23 |
| 24 | .06272 | .06691 | .06894 | .07405 | .07545 | .08161 | .08225 | .08962 | 24 |
| 25 | .06282 | .06703 | .06905 | .07417 | .07556 | .08174 | .08236 | .08975 | 25 |
| 26 | .06292 | .06715 | .06916 | .07429 | .07568 | .08187 | .08248 | .08989 | 26 |
| 27 | .06302 | .06726 | .06926 | .07442 | .07579 | .08200 | .08259 | .09003 | 27 |
| 28 | .06312 | .06738 | .06937 | .07454 | .07590 | .08213 | .08271 | .09017 | 28 |
| 29 | .06323 | .06749 | .06948 | .07466 | .07601 | .08226 | .08282 | .09030 | 29 |
| 30 | .06333 | .06761 | .06958 | .07479 | .07612 | .08239 | .08294 | .09044 | 30 |
| 31 | .06343 | .06773 | .06969 | .07491 | .07623 | .08252 | .08306 | .09058 | 31 |
| 32 | .06353 | .06784 | .06980 | .07503 | .07634 | .08265 | .08317 | .09072 | 32 |
| 33 | .06363 | .06796 | .06990 | .07516 | .07645 | .08278 | .08329 | .09086 | 33 |
| 34 | .06374 | .06807 | .07001 | .07528 | .07657 | .08291 | .08340 | .09099 | 34 |
| 35 | .06384 | .06819 | .07012 | .07540 | .07668 | .08305 | .08352 | .09113 | 35 |
| 36 | .06394 | .06831 | .07022 | .07553 | .07679 | .08318 | .08364 | .09127 | 36 |
| 37 | .06404 | .06843 | .07033 | .07565 | .07690 | .08331 | .08375 | .09141 | 37 |
| 38 | .06415 | .06854 | .07044 | .07578 | .07701 | .08344 | .08387 | .09155 | 38 |
| 39 | .06425 | .06866 | .07055 | .07590 | .07713 | .08357 | .08399 | .09169 | 39 |
| 40 | .06435 | .06878 | .07065 | .07602 | .07724 | .08370 | .08410 | .09183 | 40 |
| 41 | .06445 | .06889 | .07076 | .07615 | .07735 | .08383 | .08422 | .09197 | 41 |
| 42 | .06456 | .06901 | .07087 | .07627 | .07746 | .08397 | .08434 | .09211 | 42 |
| 43 | .06466 | .06913 | .07098 | .07640 | .07757 | .08410 | .08445 | .09224 | 43 |
| 44 | .06476 | .06925 | .07108 | .07652 | .07769 | .08423 | .08457 | .09238 | 44 |
| 45 | .06486 | .06936 | .07119 | .07665 | .07780 | .08436 | .08469 | .09252 | 45 |
| 46 | .06497 | .06948 | .07130 | .07677 | .07791 | .08449 | .08481 | .09266 | 46 |
| 47 | .06507 | .06960 | .07141 | .07690 | .07802 | .08463 | .08492 | .09280 | 47 |
| 48 | .06517 | .06972 | .07151 | .07702 | .07814 | .08476 | .08504 | .09294 | 48 |
| 49 | .06528 | .06984 | .07162 | .07715 | .07825 | .08489 | .08516 | .09308 | 49 |
| 50 | .06538 | .06995 | .07173 | .07727 | .07836 | .08503 | .08528 | .09323 | 50 |
| 51 | .06548 | .07007 | .07184 | .07740 | .07848 | .08516 | .08539 | .09337 | 51 |
| 52 | .06559 | .07019 | .07195 | .07752 | .07859 | .08529 | .08551 | .09351 | 52 |
| 53 | .06569 | .07031 | .07206 | .07765 | .07870 | .08542 | .08563 | .09365 | 53 |
| 54 | .06580 | .07043 | .07216 | .07778 | .07881 | .08556 | .08575 | .09379 | 54 |
| 55 | .06590 | .07055 | .07227 | .07790 | .07893 | .08569 | .08586 | .09393 | 55 |
| 56 | .06600 | .07067 | .07238 | .07803 | .07904 | .08582 | .08598 | .09407 | 56 |
| 57 | .06611 | .07079 | .07249 | .07816 | .07915 | .08596 | .08610 | .09421 | 57 |
| 58 | .06621 | .07091 | .07260 | .07828 | .07927 | .08609 | .08622 | .09435 | 58 |
| 59 | .06632 | .07103 | .07271 | .07841 | .07938 | .08623 | .08634 | .09449 | 59 |
| 60 | .06642 | .07115 | .07282 | .07853 | 07950 | .08636 | .08645 | .09464 | 60 |

| ′ | 24° | | 25° | | 26° | | 27° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .08645 | .09464 | .09369 | .10338 | .10121 | .11260 | .10899 | .12233 | 0 |
| 1 | .08657 | .09478 | .09382 | .10353 | .10133 | .11276 | .10913 | .12249 | 1 |
| 2 | .08669 | .09492 | .09394 | .10368 | .10146 | .11292 | .10926 | .12266 | 2 |
| 3 | .08681 | .09506 | .09406 | .10383 | .10159 | .11308 | .10939 | .12283 | 3 |
| 4 | .08693 | .09520 | .09418 | .10398 | .10172 | .11323 | .10952 | .12299 | 4 |
| 5 | .08705 | .09535 | .09431 | .10413 | .10184 | .11339 | .10965 | .12316 | 5 |
| 6 | .08717 | .09549 | .09443 | .10428 | .10197 | .11355 | .10979 | .12333 | 6 |
| 7 | .08728 | .09563 | .09455 | .10443 | .10210 | .11371 | .10992 | .12349 | 7 |
| 8 | .08740 | .09577 | .09468 | .10458 | .10223 | .11387 | .11005 | .12366 | 8 |
| 9 | .08752 | .09592 | .09480 | .10473 | .10236 | .11403 | .11019 | .12383 | 9 |
| 10 | .08764 | .09606 | .09493 | .10488 | .10248 | .11419 | .11032 | .12400 | 10 |
| 11 | .08776 | .09620 | .09505 | .10503 | .10261 | .11435 | .11045 | .12416 | 11 |
| 12 | .08788 | .09635 | .09517 | .10518 | .10274 | .11451 | .11058 | .12433 | 12 |
| 13 | .08800 | .09649 | .09530 | .10533 | .10287 | .11467 | .11072 | .12450 | 13 |
| 14 | .08812 | .09663 | .09542 | .10549 | .10300 | .11483 | .11085 | .12467 | 14 |
| 15 | .08824 | .09678 | .09554 | .10564 | .10313 | .11499 | .11098 | .12484 | 15 |
| 16 | .08836 | .09692 | .09567 | .10579 | .10326 | .11515 | .11112 | .12501 | 16 |
| 17 | .08848 | .09707 | .09579 | .10594 | .10338 | .11531 | .11125 | .12518 | 17 |
| 18 | .08860 | .09721 | .09592 | .10609 | .10351 | .11547 | .11138 | .12534 | 18 |
| 19 | .08872 | .09735 | .09604 | .10625 | .10364 | .11563 | .11152 | .12551 | 19 |
| 20 | .08884 | .09750 | .09617 | .10640 | .10377 | .11579 | .11165 | .12568 | 20 |
| 21 | .08896 | .09764 | .09629 | .10655 | .10390 | .11595 | .11178 | .12585 | 21 |
| 22 | .08908 | .09779 | .09642 | .10670 | .10403 | .11611 | .11192 | .12602 | 22 |
| 23 | .08920 | .09793 | .09654 | .10686 | .10416 | .11627 | .11205 | .12619 | 23 |
| 24 | .08932 | .09808 | .09666 | .10701 | .10429 | .11643 | .11218 | .12636 | 24 |
| 25 | .08944 | .09822 | .09679 | .10716 | .10442 | .11659 | .11232 | .12653 | 25 |
| 26 | .08956 | .09837 | .09691 | .10731 | .10455 | .11675 | .11245 | .12670 | 26 |
| 27 | .08968 | .09851 | .09704 | .10747 | .10468 | .11691 | .11259 | .12687 | 27 |
| 28 | .08980 | .09866 | .09716 | .10762 | .10481 | .11708 | .11272 | .12704 | 28 |
| 29 | .08992 | .09880 | .09729 | .10777 | .10494 | .11724 | .11285 | .12721 | 29 |
| 30 | .09004 | .09895 | .09741 | .10793 | .10507 | .11740 | .11299 | .12738 | 30 |
| 31 | .09016 | .09909 | .09754 | .10808 | .10520 | .11756 | .11312 | .12755 | 31 |
| 32 | .09028 | .09924 | .09767 | .10824 | .10533 | .11772 | .11326 | .12772 | 32 |
| 33 | .09040 | .09939 | .09779 | .10839 | .10546 | .11789 | .11339 | .12789 | 33 |
| 34 | .09052 | .09953 | .09792 | .10854 | .10559 | .11805 | .11353 | .12807 | 34 |
| 35 | .09064 | .09968 | .09804 | .10870 | .10572 | .11821 | .11366 | .12824 | 35 |
| 36 | .09076 | .09982 | .09817 | .10885 | .10585 | .11838 | .11380 | .12841 | 36 |
| 37 | .09089 | .09997 | .09829 | .10901 | .10598 | .11854 | .11393 | .12858 | 37 |
| 38 | .09101 | .10012 | .09842 | .10916 | .10611 | .11870 | .11407 | .12875 | 38 |
| 39 | .09113 | .10026 | .09854 | .10932 | .10624 | .11886 | .11420 | .12892 | 39 |
| 40 | .09125 | .10041 | .09867 | .10947 | .10637 | .11903 | .11434 | .12910 | 40 |
| 41 | .09137 | .10055 | .09880 | .10963 | .10650 | .11919 | .11447 | .12927 | 41 |
| 42 | .09149 | .10071 | .09892 | .10978 | .10663 | .11936 | .11461 | .12944 | 42 |
| 43 | .09161 | .10085 | .09905 | .10994 | .10676 | .11952 | .11474 | .12961 | 43 |
| 44 | .09174 | .10100 | .09918 | .11009 | .10689 | .11968 | .11488 | .12979 | 44 |
| 45 | .09186 | .10115 | .09930 | .11025 | .10702 | .11985 | .11501 | .12996 | 45 |
| 46 | .09198 | .10130 | .09943 | .11041 | .10715 | .12001 | .11515 | .13013 | 46 |
| 47 | .09210 | .10144 | .09955 | .11056 | .10728 | .12018 | .11528 | .13031 | 47 |
| 48 | .09222 | .10159 | .09968 | .11072 | .10741 | .12034 | .11542 | .13048 | 48 |
| 49 | .09234 | .10174 | .09981 | .11087 | .10755 | .12051 | .11555 | .13065 | 49 |
| 50 | .09247 | .10189 | .09993 | .11103 | .10768 | .12067 | .11569 | .13083 | 50 |
| 51 | .09259 | .10204 | .10006 | .11119 | .10781 | .12084 | .11583 | .13100 | 51 |
| 52 | .09271 | .10218 | .10019 | .11134 | .10794 | .12100 | .11596 | .13117 | 52 |
| 53 | .09283 | .10233 | .10032 | .11150 | .10807 | .12117 | .11610 | .13135 | 53 |
| 54 | .09296 | .10248 | .10044 | .11166 | .10820 | .12133 | .11623 | .13152 | 54 |
| 55 | .09308 | .10263 | .10057 | .11181 | .10833 | .12150 | .11637 | .13170 | 55 |
| 56 | .09320 | .10278 | .10070 | .11197 | .10847 | .12166 | .11651 | .13187 | 56 |
| 57 | .09332 | .10293 | .10082 | .11213 | .10860 | .12183 | .11664 | .13205 | 57 |
| 58 | .09345 | .10308 | .10095 | .11229 | .10873 | .12199 | .11678 | .13222 | 58 |
| 59 | .09357 | .10323 | .10108 | .11244 | .10886 | .12216 | .11692 | .13240 | 59 |
| 60 | .09369 | .10338 | .10121 | .11260 | .10899 | .12233 | .11705 | .13257 | 60 |

| ′ | 28° | | 29° | | 30° | | 31° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .11705 | .13257 | .12538 | .14335 | .13397 | .15470 | .14283 | .16663 | 0 |
| 1 | .11719 | .13275 | .12552 | .14354 | .13412 | .15489 | .14298 | .16684 | 1 |
| 2 | .11733 | .13292 | .12566 | .14372 | .13427 | .15509 | .14313 | .16704 | 2 |
| 3 | .11746 | .13310 | .12580 | .14391 | .13441 | .15528 | .14328 | .16725 | 3 |
| 4 | .11760 | .13327 | .12595 | .14409 | .13456 | .15548 | .14343 | .16745 | 4 |
| 5 | .11774 | .13345 | .12609 | .14428 | .13470 | .15567 | .14358 | .16766 | 5 |
| 6 | .11787 | .13362 | .12623 | .14446 | .13485 | .15587 | .14373 | .16786 | 6 |
| 7 | .11801 | .13380 | .12637 | .14465 | .13499 | .15606 | .14388 | .16806 | 7 |
| 8 | .11815 | .13398 | .12651 | .14483 | .13514 | .15626 | .14403 | .16827 | 8 |
| 9 | .11828 | .13415 | .12665 | .14502 | .13529 | .15645 | .14418 | .16848 | 9 |
| 10 | .11842 | .13433 | .12679 | .14521 | .13543 | .15665 | .14433 | .16868 | 10 |
| 11 | .11856 | .13451 | .12694 | .14539 | .13558 | .15684 | .14449 | .16889 | 11 |
| 12 | .11870 | .13468 | .12708 | .14558 | .13573 | .15704 | .14464 | .16909 | 12 |
| 13 | .11883 | .13486 | .12722 | .14576 | .13587 | .15724 | .14479 | .16930 | 13 |
| 14 | .11897 | .13504 | .12736 | .14595 | .13602 | .15743 | .14494 | .16950 | 14 |
| 15 | .11911 | .13521 | .12750 | .14614 | .13616 | .15763 | .14509 | .16971 | 15 |
| 16 | .11925 | .13539 | .12765 | .14632 | .13631 | .15782 | .14524 | .16992 | 16 |
| 17 | .11938 | .13557 | .12779 | .14651 | .13646 | .15802 | .14539 | .17012 | 17 |
| 18 | .11952 | .13575 | .12793 | .14670 | .13660 | .15822 | .14554 | .17033 | 18 |
| 19 | .11966 | .13593 | .12807 | .14689 | .13675 | .15841 | .14569 | .17054 | 19 |
| 20 | .11980 | .13610 | .12822 | .14707 | .13690 | .15861 | .14584 | .17075 | 20 |
| 21 | .11994 | .13628 | .12836 | .14726 | .13705 | .15881 | .14599 | .17095 | 21 |
| 22 | .12007 | .13646 | .12850 | .14745 | .13719 | .15901 | .14615 | .17116 | 22 |
| 23 | .12021 | .13664 | .12864 | .14764 | .13734 | .15920 | .14630 | .17137 | 23 |
| 24 | .12035 | .13682 | .12879 | .14782 | .13749 | .15940 | .14645 | .17158 | 24 |
| 25 | .12049 | .13700 | .12893 | .14801 | .13763 | .15960 | .14660 | .17178 | 25 |
| 26 | .12063 | .13718 | .12907 | .14820 | .13778 | .15980 | .14675 | .17199 | 26 |
| 27 | .12077 | .13735 | .12921 | .14839 | .13793 | .16000 | .14690 | .17220 | 27 |
| 28 | .12091 | .13753 | .12936 | .14858 | .13808 | .16019 | .14706 | .17241 | 28 |
| 29 | .12104 | .13771 | .12950 | .14877 | .13822 | .16039 | .14721 | .17262 | 29 |
| 30 | .12118 | .13789 | .12964 | .14896 | .13837 | .16059 | .14736 | .17283 | 30 |
| 31 | .12132 | .13807 | .12979 | .14914 | .13852 | .16079 | .14751 | .17304 | 31 |
| 32 | .12146 | .13825 | .12993 | .14933 | .13867 | .16099 | .14766 | .17325 | 32 |
| 33 | .12160 | .13843 | .13007 | .14952 | .13881 | .16119 | .14782 | .17346 | 33 |
| 34 | .12174 | .13861 | .13022 | .14971 | .13896 | .16139 | .14797 | .17367 | 34 |
| 35 | .12188 | .13879 | .13036 | .14990 | .13911 | .16159 | .14812 | .17388 | 35 |
| 36 | .12202 | .13897 | .13051 | .15009 | .13926 | .16179 | .14827 | .17409 | 36 |
| 37 | .12216 | .13916 | .13065 | .15028 | .13941 | .16199 | .14843 | .17430 | 37 |
| 38 | .12230 | .13934 | .13079 | .15047 | .13955 | .16219 | .14858 | .17451 | 38 |
| 39 | .12244 | .13952 | .13094 | .15066 | .13970 | .16239 | .14873 | .17472 | 39 |
| 40 | .12257 | .13970 | .13108 | .15085 | .13985 | .16259 | .14888 | .17493 | 40 |
| 41 | .12271 | .13988 | .13122 | .15105 | .14000 | .16279 | .14904 | .17514 | 41 |
| 42 | .12285 | .14006 | .13137 | .15124 | .14015 | .16299 | .14919 | .17535 | 42 |
| 43 | .12299 | .14024 | .13151 | .15143 | .14030 | .16319 | .14934 | .17556 | 43 |
| 44 | .12313 | .14042 | .13166 | .15162 | .14044 | .16339 | .14949 | .17577 | 44 |
| 45 | .12327 | .14061 | .13180 | .15181 | .14059 | .16359 | .14965 | .17598 | 45 |
| 46 | .12341 | .14079 | .13195 | .15200 | .14074 | .16380 | .14980 | .17620 | 46 |
| 47 | .12355 | .14097 | .13209 | .15219 | .14089 | .16400 | .14995 | .17641 | 47 |
| 48 | .12369 | .14115 | .13223 | .15239 | .14104 | .16420 | .15011 | .17662 | 48 |
| 49 | .12383 | .14134 | .13238 | .15258 | .14119 | .16440 | .15026 | .17683 | 49 |
| 50 | .12397 | .14152 | .13252 | .15277 | .14134 | .16460 | .15041 | .17704 | 50 |
| 51 | .12411 | .14170 | .13267 | .15296 | .14149 | .16481 | .15057 | .17726 | 51 |
| 52 | .12425 | .14188 | .13281 | .15315 | .14164 | .16501 | .15072 | .17747 | 52 |
| 53 | .12439 | .14207 | .13296 | .15335 | .14179 | .16521 | .15087 | .17768 | 53 |
| 54 | .12454 | .14225 | .13310 | .15354 | .14194 | .16541 | .15103 | .17790 | 54 |
| 55 | .12468 | .14243 | .13325 | .15373 | .14208 | [illegible] | .15118 | .17811 | 55 |
| 56 | .12482 | .14262 | .13339 | .15393 | .14223 | [illegible] | .15134 | .17832 | 56 |
| 57 | .12496 | .14280 | .13354 | .15412 | .14238 | [illegible] | .15149 | .17854 | 57 |
| 58 | .12510 | .14299 | .13368 | .15431 | .14253 | [illegible] | .15164 | .17875 | 58 |
| 59 | .12524 | .14317 | .13383 | .15451 | .14268 | [illegible] | .15180 | .17896 | 59 |
| 60 | .12538 | .14335 | .13397 | .15470 | .14283 | [illegible] | .15195 | .17918 | 60 |

| ′ | 32° | | 33° | | 34° | | 35° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .15195 | .17918 | .16133 | .19236 | .17096 | .20622 | .18085 | .22077 | 0 |
| 1 | .15211 | .17939 | .16149 | .19259 | .17113 | .20645 | .18101 | .22102 | 1 |
| 2 | .15226 | .17961 | .16165 | .19281 | .17129 | .20669 | .18118 | .22127 | 2 |
| 3 | .15241 | .17982 | .16181 | .19304 | .17145 | .20693 | .18135 | .22152 | 3 |
| 4 | .15257 | .18004 | .16196 | .19327 | .17161 | .20717 | .18152 | .22177 | 4 |
| 5 | .15272 | .18025 | .16212 | .19349 | .17178 | .20740 | .18168 | .22202 | 5 |
| 6 | .15288 | .18047 | .16228 | .19372 | .17194 | .20764 | .18185 | .22227 | 6 |
| 7 | .15303 | .18068 | .16244 | .19394 | .17210 | .20788 | .18202 | .22252 | 7 |
| 8 | .15319 | .18090 | .16260 | .19417 | .17227 | .20812 | .18218 | .22277 | 8 |
| 9 | .15334 | .18111 | .16276 | .19440 | .17243 | .20836 | .18235 | .22302 | 9 |
| 10 | .15350 | .18133 | .16292 | .19463 | .17259 | .20859 | .18252 | .22327 | 10 |
| 11 | .15365 | .18155 | .16308 | .19485 | .17276 | .20883 | .18269 | .22352 | 11 |
| 12 | .15381 | .18176 | .16324 | .19508 | .17292 | .20907 | .18286 | .22377 | 12 |
| 13 | .15396 | .18198 | .16340 | .19531 | .17308 | .20931 | .18302 | .22402 | 13 |
| 14 | .15412 | .18220 | .16355 | .19554 | .17325 | .20955 | .18319 | .22428 | 14 |
| 15 | .15427 | .18241 | .16371 | .19576 | .17341 | .20979 | .18336 | .22453 | 15 |
| 16 | .15443 | .18263 | .16387 | .19599 | .17357 | .21003 | .18353 | .22478 | 16 |
| 17 | .15458 | .18285 | .16403 | .19622 | .17374 | .21027 | .18369 | .22503 | 17 |
| 18 | .15474 | .18307 | .16419 | .19645 | .17390 | .21051 | .18386 | .22528 | 18 |
| 19 | .15489 | .18328 | .16435 | .19668 | .17407 | .21075 | .18403 | .22554 | 19 |
| 20 | .15505 | .18350 | .16451 | .19691 | .17423 | .21099 | .18420 | .22579 | 20 |
| 21 | .15520 | .18372 | .16467 | .19713 | .17439 | .21123 | .18437 | .22604 | 21 |
| 22 | .15536 | .18394 | .16483 | .19736 | .17456 | .21147 | .18454 | .22629 | 22 |
| 23 | .15552 | .18416 | .16499 | .19759 | .17472 | .21171 | .18470 | .22655 | 23 |
| 24 | .15567 | .18437 | .16515 | .19782 | .17489 | .21195 | .18487 | .22680 | 24 |
| 25 | .15583 | .18459 | .16531 | .19805 | .17505 | .21220 | .18504 | .22706 | 25 |
| 26 | .15598 | .18481 | .16547 | .19828 | .17522 | .21244 | .18521 | .22731 | 26 |
| 27 | .15614 | .18503 | .16563 | .19851 | .17538 | .21268 | .18538 | .22756 | 27 |
| 28 | .15630 | .18525 | .16579 | .19874 | .17554 | .21292 | .18555 | .22782 | 28 |
| 29 | .15645 | .18547 | .16595 | .19897 | .17571 | .21316 | .18572 | .22807 | 29 |
| 30 | .15661 | .18569 | .16611 | .19920 | .17587 | .21341 | .18588 | .22833 | 30 |
| 31 | .15676 | .18591 | .16627 | .19944 | .17604 | .21365 | .18605 | .22858 | 31 |
| 32 | .15692 | .18613 | .16644 | .19967 | .17620 | .21389 | .18622 | .22884 | 32 |
| 33 | .15708 | .18635 | .16660 | .19990 | .17637 | .21414 | .18639 | .22909 | 33 |
| 34 | .15723 | .18657 | .16676 | .20013 | .17653 | .21438 | .18656 | .22935 | 34 |
| 35 | .15739 | .18679 | .16692 | .20036 | .17670 | .21462 | .18673 | .22960 | 35 |
| 36 | .15755 | .18701 | .16708 | .20059 | .17686 | .21487 | .18690 | .22986 | 36 |
| 37 | .15770 | .18723 | .16724 | .20083 | .17703 | .21511 | .18707 | .23012 | 37 |
| 38 | .15786 | .18745 | .16740 | .20106 | .17719 | .21535 | .18724 | .23037 | 38 |
| 39 | .15802 | .18767 | .16756 | .20129 | .17736 | .21560 | .18741 | .23063 | 39 |
| 40 | .15818 | .18790 | .16772 | .20152 | .17752 | .21584 | .18758 | .23089 | 40 |
| 41 | .15833 | .18812 | .16788 | .20176 | .17769 | .21609 | .18775 | .23114 | 41 |
| 42 | .15849 | .18834 | .16805 | .20199 | .17786 | .21633 | .18792 | .23140 | 42 |
| 43 | .15865 | .18856 | .16821 | .20222 | .17802 | .21658 | .18809 | .23166 | 43 |
| 44 | .15880 | .18878 | .16837 | .20246 | .17819 | .21682 | .18826 | .23192 | 44 |
| 45 | .15896 | .18901 | .16853 | .20269 | .17835 | .21707 | .18843 | .23217 | 45 |
| 46 | .15912 | .18923 | .16869 | .20292 | .17852 | .21731 | .18860 | .23243 | 46 |
| 47 | .15928 | .18945 | .16885 | .20316 | .17868 | .21756 | .18877 | .23269 | 47 |
| 48 | .15943 | .18967 | .16902 | .20339 | .17885 | .21781 | .18894 | .23295 | 48 |
| 49 | .15959 | .18990 | .16918 | .20363 | .17902 | .21805 | .18911 | .23321 | 49 |
| 50 | .15975 | .19012 | .16934 | .20386 | .17918 | .21830 | .18928 | .23347 | 50 |
| 51 | .15991 | .19034 | .16950 | .20410 | .17935 | .21855 | .18945 | .23373 | 51 |
| 52 | .16006 | .19057 | .16966 | .20433 | .17952 | .21879 | .18962 | .23399 | 52 |
| 53 | .16022 | .19079 | .16983 | .20457 | .17968 | .21904 | .18979 | .23424 | 53 |
| 54 | .16038 | .19102 | .16999 | .20480 | .17985 | .21929 | .18996 | .23450 | 54 |
| 55 | .16054 | .19124 | .17015 | .20504 | .18001 | .21953 | .19013 | .23476 | 55 |
| 56 | .16070 | .19146 | .17031 | .20527 | .18018 | .21978 | .19030 | .23502 | 56 |
| 57 | .16085 | .19169 | .17047 | .20551 | .18035 | .22003 | .19047 | .23529 | 57 |
| 58 | .16101 | .19191 | .17064 | .20575 | .18051 | .22028 | .19064 | .23555 | 58 |
| 59 | .16117 | .19214 | .17080 | .20598 | .18068 | .22053 | .19081 | .23581 | 59 |
| 60 | .16133 | .19236 | .17096 | .20622 | .18085 | .22077 | .19098 | .23607 | 60 |

| ′ | 36° |  | 37° |  | 38° |  | 39° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .19098 | .23607 | .20136 | .25214 | .21199 | .26902 | .22285 | .28676 | 0 |
| 1 | .19115 | .23633 | .20154 | .25241 | .21217 | .26931 | .22304 | .28706 | 1 |
| 2 | .19133 | .23659 | .20171 | .25269 | .21235 | .26960 | .22322 | .28737 | 2 |
| 3 | .19150 | .23685 | .20189 | .25296 | .21253 | .26988 | .22340 | .28767 | 3 |
| 4 | .19167 | .23711 | .20207 | .25324 | .21271 | .27017 | .22359 | .28797 | 4 |
| 5 | .19184 | .23738 | .20224 | .25351 | .21289 | .27046 | .22377 | .28828 | 5 |
| 6 | .19201 | .23764 | .20242 | .25379 | .21307 | .27075 | .22395 | .28858 | 6 |
| 7 | .19218 | .23790 | .20259 | .25406 | .21324 | .27104 | .22414 | .28889 | 7 |
| 8 | .19235 | .23816 | .20277 | .25434 | .21342 | .27133 | .22432 | .28919 | 8 |
| 9 | .19252 | .23843 | .20294 | .25462 | .21360 | .27162 | .22450 | .28950 | 9 |
| 10 | .19270 | .23869 | .20312 | .25489 | .21378 | .27191 | .22469 | .28980 | 10 |
| 11 | .19287 | .23895 | .20329 | .25517 | .21396 | .27221 | .22487 | .29011 | 11 |
| 12 | .19304 | .23922 | .20347 | .25545 | .21414 | .27250 | .22506 | .29042 | 12 |
| 13 | .19321 | .23948 | .20365 | .25572 | .21432 | .27279 | .22524 | .29072 | 13 |
| 14 | .19338 | .23975 | .20382 | .25600 | .21450 | .27308 | .22542 | .29103 | 14 |
| 15 | .19356 | .24001 | .20400 | .25628 | .21468 | .27337 | .22561 | .29133 | 15 |
| 16 | .19373 | .24028 | .20417 | .25656 | .21486 | .27366 | .22579 | .29164 | 16 |
| 17 | .19390 | .24054 | .20435 | .25683 | .21504 | .27396 | .22598 | .29195 | 17 |
| 18 | .19407 | .24081 | .20453 | .25711 | .21522 | .27425 | .22616 | .29226 | 18 |
| 19 | .19424 | .24107 | .20470 | .25739 | .21540 | .27454 | .22634 | .29256 | 19 |
| 20 | .19442 | .24134 | .20488 | .25767 | .21558 | .27483 | .22653 | .29287 | 20 |
| 21 | .19459 | .24160 | .20506 | .25795 | .21576 | .27513 | .22671 | .29318 | 21 |
| 22 | .19476 | .24187 | .20523 | .25823 | .21595 | .27542 | .22690 | .29349 | 22 |
| 23 | .19493 | .24213 | .20541 | .25851 | .21613 | .27572 | .22708 | .29380 | 23 |
| 24 | .19511 | .24240 | .20559 | .25879 | .21631 | .27601 | .22727 | .29411 | 24 |
| 25 | .19528 | .24267 | .20576 | .25907 | .21649 | .27630 | .22745 | .29442 | 25 |
| 26 | .19545 | .24293 | .20594 | .25935 | .21667 | .27660 | .22764 | .29473 | 26 |
| 27 | .19562 | .24320 | .20612 | .25963 | .21685 | .27689 | .22782 | .29504 | 27 |
| 28 | .19580 | .24347 | .20629 | .25991 | .21703 | .27719 | .22801 | .29535 | 28 |
| 29 | .19597 | .24373 | .20647 | .26019 | .21721 | .27748 | .22819 | .29566 | 29 |
| 30 | .19614 | .24400 | .20665 | .26047 | .21739 | .27778 | .22838 | .29597 | 30 |
| 31 | .19632 | .24427 | .20682 | .26075 | .21757 | .27807 | .22856 | .29628 | 31 |
| 32 | .19649 | .24454 | .20700 | .26104 | .21775 | .27837 | .22875 | .29659 | 32 |
| 33 | .19666 | .24481 | .20718 | .26132 | .21794 | .27867 | .22893 | .29690 | 33 |
| 34 | .19684 | .24508 | .20736 | .26160 | .21812 | .27896 | .22912 | .29721 | 34 |
| 35 | .19701 | .24534 | .20753 | .26188 | .21830 | .27926 | .22930 | .29752 | 35 |
| 36 | .19718 | .24561 | .20771 | .26216 | .21848 | .27956 | .22949 | .29784 | 36 |
| 37 | .19736 | .24588 | .20789 | .26245 | .21866 | .27985 | .22967 | .29815 | 37 |
| 38 | .19753 | .24615 | .20807 | .26273 | .21884 | .28015 | .22986 | .29846 | 38 |
| 39 | .19770 | .24642 | .20824 | .26301 | .21902 | .28045 | .23004 | .29877 | 39 |
| 40 | .19788 | .24669 | .20842 | .26330 | .21921 | .28075 | .23023 | .29909 | 40 |
| 41 | .19805 | .24696 | .20860 | .26358 | .21939 | .28105 | .23041 | .29940 | 41 |
| 42 | .19822 | .24723 | .20878 | .26387 | .21957 | .28134 | .23060 | .29971 | 42 |
| 43 | .19840 | .24750 | .20895 | .26415 | .21975 | .28164 | .23079 | .30003 | 43 |
| 44 | .19857 | .24777 | .20913 | .26443 | .21993 | .28194 | .23097 | .30034 | 44 |
| 45 | .19875 | .24804 | .20931 | .26472 | .22012 | .28224 | .23116 | .30066 | 45 |
| 46 | .19892 | .24832 | .20949 | .26500 | .22030 | .28254 | .23134 | .30097 | 46 |
| 47 | .19909 | .24859 | .20967 | .26529 | .22048 | .28284 | .23153 | .30129 | 47 |
| 48 | .19927 | .24886 | .20985 | .26557 | .22066 | .28314 | .23172 | .30160 | 48 |
| 49 | .19944 | .24913 | .21002 | .26586 | .22084 | .28344 | .23190 | .30192 | 49 |
| 50 | .19962 | .24940 | .21020 | .26615 | .22103 | .28374 | .23209 | .30223 | 50 |
| 51 | .19979 | .24967 | .21038 | .26643 | .22121 | .28404 | .23228 | .30255 | 51 |
| 52 | .19997 | .24995 | .21056 | .26672 | .22139 | .28434 | .23246 | .30287 | 52 |
| 53 | .20014 | .25022 | .21074 | .26701 | .22157 | .28464 | .23265 | .30318 | 53 |
| 54 | .20032 | .25049 | .21092 | .26729 | .22176 | .28495 | .23283 | .30350 | 54 |
| 55 | .20049 | .25077 | .21109 | .26758 | .22194 | .28525 | .23302 | .30382 | 55 |
| 56 | .20066 | .25104 | .21127 | .26787 | .22212 | .28555 | .23321 | .30413 | 56 |
| 57 | .20084 | .25131 | .21145 | .26815 | .22231 | .28585 | .23339 | .30445 | 57 |
| 58 | .20101 | .25159 | .21163 | .26844 | .22249 | .28615 | .23358 | .30477 | 58 |
| 59 | .20119 | .25186 | .21181 | .26873 | .22267 | .28646 | .23377 | .30509 | 59 |
| 60 | .20136 | .25214 | .21199 | .26902 | .22285 | .28676 | .23396 | .30541 | 60 |

| ′ | 40° | | 41° | | 42° | | 43° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .23396 | .30541 | .24529 | .32501 | .25686 | .34563 | .26865 | .36733 | 0 |
| 1 | .23414 | .30573 | .24548 | .32535 | .25705 | .34599 | .26884 | .36770 | 1 |
| 2 | .23433 | .30605 | .24567 | .32568 | .25724 | .34634 | .26904 | .36807 | 2 |
| 3 | .23452 | .30636 | .24586 | .32602 | .25744 | .34669 | .26924 | .36844 | 3 |
| 4 | .23470 | .30668 | .24605 | .32636 | .25763 | .34704 | .26944 | .36881 | 4 |
| 5 | .23489 | .30700 | .24625 | .32669 | .25783 | .34740 | .26964 | .36919 | 5 |
| 6 | .23508 | .30732 | .24644 | .32703 | .25802 | .34775 | .26984 | .36956 | 6 |
| 7 | .23527 | .30764 | .24663 | .32737 | .25822 | .34811 | .27004 | .36993 | 7 |
| 8 | .23545 | .30796 | .24682 | .32770 | .25841 | .34846 | .27024 | .37030 | 8 |
| 9 | .23564 | .30829 | .24701 | .32804 | .25861 | .34882 | .27043 | .37068 | 9 |
| 10 | .23583 | .30861 | .24720 | .32838 | .25880 | .34917 | .27063 | .37105 | 10 |
| 11 | .23602 | .30893 | .24739 | .32872 | .25900 | .34953 | .27083 | .37143 | 11 |
| 12 | .23620 | .30925 | .24759 | .32905 | .25920 | .34988 | .27103 | .37180 | 12 |
| 13 | .23639 | .30957 | .24778 | .32939 | .25939 | .35024 | .27123 | .37218 | 13 |
| 14 | .23658 | .30989 | .24797 | .32973 | .25959 | .35060 | .27143 | .37255 | 14 |
| 15 | .23677 | .31022 | .24816 | .33007 | .25978 | .35095 | .27163 | .37293 | 15 |
| 16 | .23696 | .31054 | .24835 | .33041 | .25998 | .35131 | .27183 | .37330 | 16 |
| 17 | .23714 | .31086 | .24854 | .33075 | .26017 | .35167 | .27203 | .37368 | 17 |
| 18 | .23733 | .31119 | .24874 | .33109 | .26037 | .35203 | .27223 | .37406 | 18 |
| 19 | .23752 | .31151 | .24893 | .33143 | .26056 | .35238 | .27243 | .37443 | 19 |
| 20 | .23771 | .31183 | .24912 | .33177 | .26076 | .35274 | .27263 | .37481 | 20 |
| 21 | .23790 | .31216 | .24931 | .33211 | .26096 | .35310 | .27283 | .37519 | 21 |
| 22 | .23808 | .31248 | .24950 | .33245 | .26115 | .35346 | .27303 | .37556 | 22 |
| 23 | .23827 | .31281 | .24970 | .33279 | .26135 | .35382 | .27323 | .37594 | 23 |
| 24 | .23846 | .31313 | .24989 | .33314 | .26154 | .35418 | .27343 | .37632 | 24 |
| 25 | .23865 | .31346 | .25008 | .33348 | .26174 | .35454 | .27363 | .37670 | 25 |
| 26 | .23884 | .31378 | .25027 | .33382 | .26194 | .35490 | .27383 | .37708 | 26 |
| 27 | .23903 | .31411 | .25047 | .33416 | .26213 | .35526 | .27403 | .37746 | 27 |
| 28 | .23922 | .31443 | .25066 | .33451 | .26233 | .35562 | .27423 | .37784 | 28 |
| 29 | .23941 | .31476 | .25085 | .33485 | .26253 | .35598 | .27443 | .27822 | 29 |
| 30 | .23959 | .31509 | .25104 | .33519 | .26272 | .35634 | .27463 | .37860 | 30 |
| 31 | .23978 | .31541 | .25124 | .33554 | .26292 | .35670 | .27483 | .37898 | 31 |
| 32 | .23997 | .31574 | .25143 | .33588 | .26312 | .35707 | .27503 | .37936 | 32 |
| 33 | .24016 | .31607 | .25162 | .33622 | .26331 | .35743 | .27523 | .37974 | 33 |
| 34 | .24035 | .31640 | .25182 | .33657 | .26351 | .35779 | .27543 | .38012 | 34 |
| 35 | .24054 | .31672 | .25201 | .33691 | .26371 | .35815 | .27563 | .38051 | 35 |
| 36 | .24073 | .31705 | .25220 | .33726 | .26390 | .35852 | .27583 | .38089 | 36 |
| 37 | .24092 | .31738 | .25240 | .33760 | .26410 | .35888 | .27603 | .38127 | 37 |
| 38 | .24111 | .31771 | .25259 | .33795 | .26430 | .35924 | .27623 | .38165 | 38 |
| 39 | .24130 | .31804 | .25278 | .33830 | .26449 | .35961 | .27643 | .38204 | 39 |
| 40 | .24149 | .31837 | .25297 | .33864 | .26469 | .35997 | .27663 | .38242 | 40 |
| 41 | .24168 | .31870 | .25317 | .33899 | .26489 | .36034 | .27683 | .38280 | 41 |
| 42 | .24187 | .31903 | .25336 | .33934 | .26509 | .36070 | .27703 | .38319 | 42 |
| 43 | .24206 | .31936 | .25356 | .33968 | .26528 | .36107 | .27723 | .38357 | 43 |
| 44 | .24225 | .31969 | .25375 | .34003 | .26548 | .36143 | .27743 | .38396 | 44 |
| 45 | .24244 | .32002 | .25394 | .34038 | .26568 | .36180 | .27764 | .38434 | 45 |
| 46 | .24262 | .32035 | .25414 | .34073 | .26588 | .36217 | .27784 | .38473 | 46 |
| 47 | .24281 | .32068 | .25433 | .34108 | .26607 | .36253 | .27804 | .38512 | 47 |
| 48 | .24300 | .32101 | .25452 | .34142 | .26627 | .36290 | .27824 | .38550 | 48 |
| 49 | .24320 | .32134 | .25472 | .34177 | .26647 | .36327 | .27844 | .38589 | 49 |
| 50 | .24339 | .32168 | .25491 | .34212 | .26667 | .36363 | .27864 | .38628 | 50 |
| 51 | .24358 | .32201 | .25511 | .34247 | .26686 | .36400 | .27884 | .38668 | 51 |
| 52 | .24377 | .32234 | .25530 | .34282 | .26706 | .36437 | .27905 | .38705 | 52 |
| 53 | .24396 | .32267 | .25549 | .34317 | .26726 | .36474 | .27925 | .38744 | 53 |
| 54 | .24415 | .32301 | .25569 | .34352 | .26746 | .36511 | .27945 | .38783 | 54 |
| 55 | .24434 | .32334 | .25588 | .34387 | .26766 | .36548 | .27965 | .38822 | 55 |
| 56 | .24453 | .32368 | .25608 | .34423 | .26785 | .36585 | .27985 | .38860 | 56 |
| 57 | .24472 | .32401 | .25627 | .34458 | .26805 | .36622 | .28005 | .38899 | 57 |
| 58 | .24491 | .32434 | .25647 | .34493 | .26825 | .36659 | .28026 | .38938 | 58 |
| 59 | .24510 | .32468 | .25666 | .34528 | .26845 | .36696 | .28046 | .38977 | 59 |
| 60 | .24529 | .32501 | .25686 | .34563 | .26865 | .36733 | .28066 | .39016 | 60 |

| ′ | 44° |  | 45° |  | 46° |  | 47° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .28066 | .39016 | .29289 | .41421 | .30534 | .43956 | .31800 | .46628 | 0 |
| 1 | .28086 | .39055 | .29310 | .41463 | .30555 | .43999 | .31821 | .46674 | 1 |
| 2 | .28106 | .39095 | .29330 | .41504 | .30576 | .44042 | .31843 | .46719 | 2 |
| 3 | .28127 | .39134 | .29351 | .41545 | .30597 | .44086 | .31864 | .46765 | 3 |
| 4 | .28147 | .39173 | .29372 | .41586 | .30618 | .44129 | .31885 | .46811 | 4 |
| 5 | .28167 | .39212 | .29392 | .41627 | .30639 | .44173 | .31907 | .46857 | 5 |
| 6 | .28187 | .39251 | .29413 | .41669 | .30660 | .44217 | .31928 | .46903 | 6 |
| 7 | .28208 | .39291 | .29433 | .41710 | .30681 | .44260 | .31949 | .46949 | 7 |
| 8 | .28228 | .39330 | .29454 | .41752 | .30702 | .44304 | .31971 | .46995 | 8 |
| 9 | .28248 | .39369 | .29475 | .41793 | .30723 | .44347 | .31992 | .47041 | 9 |
| 10 | .28268 | .39409 | .29495 | .41835 | .30744 | .44391 | .32013 | .47087 | 10 |
| 11 | .28289 | .39448 | .29516 | .41876 | .30765 | .44435 | .32035 | .47134 | 11 |
| 12 | .28309 | .39487 | .29537 | .41918 | .30786 | .44479 | .32056 | .47180 | 12 |
| 13 | .28329 | .39527 | .29557 | .41959 | .30807 | .44523 | .32077 | .47226 | 13 |
| 14 | .28350 | .39566 | .29578 | .42001 | .30828 | .44567 | .32099 | .47272 | 14 |
| 15 | .28370 | .39606 | .29599 | .42042 | .30849 | .44610 | .32120 | .47319 | 15 |
| 16 | .28390 | .39646 | .29619 | .42084 | .30870 | .44654 | .32141 | .47365 | 16 |
| 17 | .28410 | .39685 | .29640 | .42126 | .30891 | .44698 | .32163 | .47411 | 17 |
| 18 | .28431 | .39725 | .29661 | .42168 | .30912 | .44742 | .32184 | .47458 | 18 |
| 19 | .28451 | .39764 | .29681 | .42210 | .30933 | .44787 | .32205 | .47504 | 19 |
| 20 | .28471 | .39804 | .29702 | .42251 | .30954 | .44831 | .32227 | .47551 | 20 |
| 21 | .28492 | .39844 | .29723 | .42293 | .30975 | .44875 | .32248 | .47598 | 21 |
| 22 | .28512 | .39884 | .29743 | .42335 | .30996 | .44919 | .32270 | .47644 | 22 |
| 23 | .28532 | .39924 | .29764 | .42377 | .31017 | .44963 | .32291 | .47691 | 23 |
| 24 | .28553 | .39963 | .29785 | .42419 | .31038 | .45007 | .32312 | .47738 | 24 |
| 25 | .28573 | .40003 | .29805 | .42461 | .31059 | .45052 | .32334 | .47784 | 25 |
| 26 | .28593 | .40043 | .29826 | .42503 | .31080 | .45096 | .32355 | .47831 | 26 |
| 27 | .28614 | .40083 | .29847 | .42545 | .31101 | .45141 | .32377 | .47878 | 27 |
| 28 | .28634 | .40123 | .29868 | .42587 | .31122 | .45185 | .32398 | .47925 | 28 |
| 29 | .28655 | .40163 | .29888 | .42630 | .31143 | .45229 | .32420 | .47972 | 29 |
| 30 | .28675 | .40203 | .29909 | .42672 | .31165 | .45274 | .32441 | .48019 | 30 |
| 31 | .28695 | .40243 | .29930 | .42714 | .31186 | .45319 | .32462 | .48066 | 31 |
| 32 | .28716 | .40283 | .29951 | .42756 | .31207 | .45363 | .32484 | .48113 | 32 |
| 33 | .28736 | .40324 | .29971 | .42799 | .31228 | .45408 | .32505 | .48160 | 33 |
| 34 | .28757 | .40364 | .29992 | .42841 | .31249 | .45452 | .32527 | .48207 | 34 |
| 35 | .28777 | .40404 | .30013 | .42883 | .31270 | .45497 | .32548 | .48254 | 35 |
| 36 | .28797 | .40444 | .30034 | .42926 | .31291 | .45542 | .32570 | .48301 | 36 |
| 37 | .28818 | .40485 | .30054 | .42968 | .31312 | .45587 | .32591 | .48349 | 37 |
| 38 | .28838 | .40525 | .30075 | .43011 | .31334 | .45631 | .32613 | .48396 | 38 |
| 39 | .28859 | .40565 | .30096 | .43053 | .31355 | .45676 | .32634 | .48443 | 39 |
| 40 | .28879 | .40606 | .30117 | .43096 | .31376 | .45721 | .32656 | .48491 | 40 |
| 41 | .28900 | .40646 | .30138 | .43139 | .31397 | .45766 | .32677 | .48538 | 41 |
| 42 | .28920 | .40687 | .30158 | .43181 | .31418 | .45811 | .32699 | .48586 | 42 |
| 43 | .28941 | .40727 | .30179 | .43224 | .31439 | .45856 | .32720 | .48633 | 43 |
| 44 | .28961 | .40768 | .30200 | .43267 | .31461 | .45901 | .32742 | .48681 | 44 |
| 45 | .28981 | .40808 | .30221 | .43310 | .31482 | .45946 | .32763 | .48728 | 45 |
| 46 | .29002 | .40849 | .30242 | .43352 | .31503 | .45992 | .32785 | .48776 | 46 |
| 47 | .29022 | .40890 | .30263 | .43395 | .31524 | .46037 | .32806 | .48824 | 47 |
| 48 | .29043 | .40930 | .30283 | .43438 | .31545 | .46082 | .32828 | .48871 | 48 |
| 49 | .29063 | .40971 | .30304 | .43481 | .31567 | .46127 | .32849 | .48919 | 49 |
| 50 | .29084 | .41012 | .30325 | .43524 | .31588 | .46173 | .32871 | .48967 | 50 |
| 51 | .29104 | .41053 | .30346 | .43567 | .31609 | .46218 | .32893 | .49015 | 51 |
| 52 | .29125 | .41093 | .30367 | .43610 | .31630 | .46263 | .32914 | .49063 | 52 |
| 53 | .29145 | .41134 | .30388 | .43653 | .31651 | .46309 | .32936 | .49111 | 53 |
| 54 | .29166 | .41175 | .30409 | .43696 | .31673 | .46354 | .32957 | .49159 | 54 |
| 55 | .29187 | .41216 | .30430 | .43739 | .31694 | .46400 | .32979 | .49207 | 55 |
| 56 | .29207 | .41257 | .30451 | .43783 | .31715 | .46445 | .33001 | .49255 | 56 |
| 57 | .29228 | .41298 | .30471 | .43826 | .31736 | .46491 | .33022 | .49303 | 57 |
| 58 | .29248 | .41339 | .30492 | .43869 | .31758 | .46537 | .33044 | .49351 | 58 |
| 59 | .29269 | .41380 | .30513 | .43912 | .31779 | .46582 | .33065 | .49399 | 59 |
| 60 | .29289 | .41421 | .30534 | .43956 | .31800 | .46628 | .33087 | .49448 | 60 |

| ′ | 48° | | 49° | | 50° | | 51° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .33087 | .49448 | .34394 | .52425 | .35721 | .55572 | .37068 | .58902 | 0 |
| 1 | .33109 | .49496 | .34416 | .52476 | .35744 | .55626 | .37091 | .58959 | 1 |
| 2 | .33130 | .49544 | .34438 | .52527 | .35766 | .55680 | .37113 | .59016 | 2 |
| 3 | .33152 | .49593 | .34460 | .52579 | .35788 | .55734 | .37136 | .59073 | 3 |
| 4 | .33173 | .49641 | .34482 | .52630 | .35810 | .55789 | .37158 | .59130 | 4 |
| 5 | .33195 | .49690 | .34504 | .52681 | .35833 | .55843 | .37181 | .59188 | 5 |
| 6 | .33217 | .49738 | .34526 | .52732 | .35855 | .55897 | .37204 | .59245 | 6 |
| 7 | .33238 | .49787 | .34548 | .52784 | .35877 | .55951 | .37226 | .59302 | 7 |
| 8 | .33260 | .49835 | .34570 | .52835 | .35900 | .56005 | .37249 | .59360 | 8 |
| 9 | .33282 | .49884 | .34592 | .52886 | .35922 | .56060 | .37272 | .59418 | 9 |
| 10 | .33303 | .49933 | .34614 | .52938 | .35944 | .56114 | .37294 | .59475 | 10 |
| 11 | .33325 | .49981 | .34636 | .52989 | .35967 | .56169 | .37317 | .59533 | 11 |
| 12 | .33347 | .50030 | .34658 | .53041 | .35989 | .56223 | .37340 | .59590 | 12 |
| 13 | .33368 | .50079 | .34680 | .53092 | .36011 | .56278 | .37362 | .59648 | 13 |
| 14 | .33390 | .50128 | .34702 | .53144 | .36034 | .56332 | .37385 | .59706 | 14 |
| 15 | .33412 | .50177 | .34724 | .53196 | .36056 | .56387 | .37408 | .59764 | 15 |
| 16 | .33434 | .50226 | .34746 | .53247 | .36078 | .56442 | .37430 | .59822 | 16 |
| 17 | .33455 | .50275 | .34768 | .53299 | .36101 | .56497 | .37453 | .59880 | 17 |
| 18 | .33477 | .50324 | .34790 | .53351 | .36123 | .56551 | .37476 | .59938 | 18 |
| 19 | .33499 | .50373 | .34812 | .53403 | .36146 | .56606 | .37498 | .59996 | 19 |
| 20 | .33520 | .50422 | .34834 | .53455 | .36168 | .56661 | .37521 | .60054 | 20 |
| 21 | .33542 | .50471 | .34856 | .53507 | .36190 | .56716 | .37544 | .60112 | 21 |
| 22 | .33564 | .50521 | .34878 | .53559 | .36213 | .56771 | .37567 | .60171 | 22 |
| 23 | .33586 | .50570 | .34900 | .53611 | .36235 | .56826 | .37589 | .60229 | 23 |
| 24 | .33607 | .50619 | .34923 | .53663 | .36258 | .56881 | .37612 | .60287 | 24 |
| 25 | .33629 | .50669 | .34945 | .53715 | .36280 | .56937 | .37635 | .60346 | 25 |
| 26 | .33651 | .50718 | .34967 | .53768 | .36302 | .56992 | .37658 | .60404 | 26 |
| 27 | .33673 | .50767 | .34989 | .53820 | .36325 | .57047 | .37680 | .60463 | 27 |
| 28 | .33694 | .50817 | .35011 | .53872 | .36347 | .57103 | .37703 | .60521 | 28 |
| 29 | .33716 | .50866 | .35033 | .53924 | .36370 | .57158 | .37726 | .60580 | 29 |
| 30 | .33738 | .50916 | .35055 | .53977 | .36392 | .57213 | .37749 | .60639 | 30 |
| 31 | .33760 | .50966 | .35077 | .54029 | .36415 | .57269 | .37771 | .60698 | 31 |
| 32 | .33782 | .51015 | .35099 | .54082 | .36437 | .57324 | .37794 | .60756 | 32 |
| 33 | .33803 | .51065 | .35122 | .54134 | .36460 | .57380 | .37817 | .60815 | 33 |
| 34 | .33825 | .51115 | .35144 | .54187 | .36482 | .57436 | .37840 | .60874 | 34 |
| 35 | .33847 | .51165 | .35166 | .54240 | .36504 | .57491 | .37862 | .60933 | 35 |
| 36 | .33869 | .51215 | .35188 | .54292 | .36527 | .57547 | .37885 | .60992 | 36 |
| 37 | .33891 | .51265 | .35210 | .54345 | .36549 | .57603 | .37908 | .61051 | 37 |
| 38 | .33912 | .51314 | .35232 | .54398 | .36572 | .57659 | .37931 | .61111 | 38 |
| 39 | .33934 | .51364 | .35254 | .54451 | .36594 | .57715 | .37954 | .61170 | 39 |
| 40 | .33956 | .51415 | .35277 | .54504 | .36617 | .57771 | .37976 | .61229 | 40 |
| 41 | .33978 | .51465 | .35299 | .54557 | .36639 | .57827 | .37999 | .61288 | 41 |
| 42 | .34000 | .51515 | .35321 | .54610 | .36662 | .57883 | .38022 | .61348 | 42 |
| 43 | .34022 | .51565 | .35343 | .54663 | .36684 | .57939 | .38045 | .61407 | 43 |
| 44 | .34044 | .51615 | .35365 | .54716 | .36707 | .57995 | .38068 | .61467 | 44 |
| 45 | .34065 | .51665 | .35388 | .54769 | .36729 | .58051 | .38091 | .61526 | 45 |
| 46 | .34087 | .51716 | .35410 | .54822 | .36752 | .58108 | .38113 | .61586 | 46 |
| 47 | .34109 | .51766 | .35432 | .54876 | .36775 | .58164 | .38136 | .61646 | 47 |
| 48 | .34131 | .51817 | .35454 | .54929 | .36797 | .58221 | .38159 | .61705 | 48 |
| 49 | .34153 | .51867 | .35476 | .54982 | .36820 | .58277 | .38182 | .61765 | 49 |
| 50 | .34175 | .51918 | .35499 | .55036 | .36842 | .58333 | .38205 | .61825 | 50 |
| 51 | .34197 | .51968 | .35521 | .55089 | .36865 | .58390 | .38228 | .61885 | 51 |
| 52 | .34219 | .52019 | .35543 | .55143 | .36887 | .58447 | .38251 | .61945 | 52 |
| 53 | .34241 | .52069 | .35565 | .55196 | .36910 | .58503 | .38274 | .62005 | 53 |
| 54 | .34262 | .52120 | .35588 | .55250 | .36932 | .58560 | .38296 | .62065 | 54 |
| 55 | .34284 | .52171 | .35610 | .55303 | .36955 | .58617 | .38319 | .62125 | 55 |
| 56 | .34306 | .52222 | .35632 | .55357 | .36978 | .58674 | .38342 | .62185 | 56 |
| 57 | .34328 | .52273 | .35654 | .55411 | .37000 | .58731 | .38365 | .62246 | 57 |
| 58 | .34350 | .52323 | .35677 | .55465 | .37023 | .58788 | .38388 | .62306 | 58 |
| 59 | .34372 | .52374 | .35699 | .55518 | .37045 | .58845 | .38411 | .62366 | 59 |
| 60 | .34394 | .52425 | .35721 | .55572 | .37068 | .58902 | .38434 | .62427 | 60 |

| ′ | 52° |  | 53° |  | 54° |  | 55° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .38434 | .62427 | .39819 | .06164 | .41221 | .70130 | .42642 | .74345 | 0 |
| 1 | .38457 | .62487 | .39842 | .66228 | .41245 | .70198 | .42666 | .74417 | 1 |
| 2 | .38480 | .62548 | .39865 | .66292 | .41269 | .70267 | .42690 | .74490 | 2 |
| 3 | .38503 | .62609 | .39888 | .66357 | .41292 | .70335 | .42714 | .74562 | 3 |
| 4 | .38526 | .62669 | .39911 | .66421 | .41316 | .70403 | .42738 | .74635 | 4 |
| 5 | .38549 | .62730 | .39935 | .66486 | .41339 | .70472 | .42762 | .74708 | 5 |
| 6 | .38571 | .62791 | .39958 | .66550 | .41363 | .70540 | .42785 | .74781 | 6 |
| 7 | .38594 | .62852 | .39981 | .66615 | .41386 | .70609 | .42809 | .74854 | 7 |
| 8 | .38617 | .62913 | .40005 | .66679 | .41410 | .70677 | .42833 | .74927 | 8 |
| 9 | .38640 | .62974 | .40028 | .66744 | .41433 | .70746 | .42857 | .75000 | 9 |
| 10 | .38663 | .63035 | .40051 | .66809 | .41457 | .70815 | .42881 | .75073 | 10 |
| 11 | .38686 | .63096 | .40074 | .66873 | .41481 | .70884 | .42905 | .75146 | 11 |
| 12 | .38709 | .63157 | .40098 | .66938 | .41504 | .70953 | .42929 | .75219 | 12 |
| 13 | .38732 | .63218 | .40121 | .67003 | .41528 | .71022 | .42953 | .75293 | 13 |
| 14 | .38755 | .63279 | .40144 | .67068 | .41551 | .71091 | .42976 | .75366 | 14 |
| 15 | .38778 | .63341 | .40168 | .67133 | .41575 | .71160 | .43000 | .75440 | 15 |
| 16 | .38801 | .63402 | .40191 | .67199 | .41599 | .71229 | .43024 | .75513 | 16 |
| 17 | .38824 | .63464 | .40214 | .67264 | .41622 | .71298 | .43048 | .75587 | 17 |
| 18 | .38847 | .63525 | .40237 | .67329 | .41646 | .71368 | .43072 | .75661 | 18 |
| 19 | .38870 | .63587 | .40261 | .67394 | .41670 | .71437 | .43096 | .75734 | 19 |
| 20 | .38893 | .63648 | .40284 | .67460 | .41693 | .71506 | .43120 | .75808 | 20 |
| 21 | .38916 | .63710 | .40307 | .67525 | .41717 | .71576 | .43144 | .75882 | 21 |
| 22 | .38939 | .63772 | .40331 | .67591 | .41740 | .71646 | .43168 | .75956 | 22 |
| 23 | .38962 | .63834 | .40354 | .67656 | .41764 | .71715 | .43192 | .76031 | 23 |
| 24 | .38985 | .63895 | .40378 | .67722 | .41788 | .71785 | .43216 | .76105 | 24 |
| 25 | .39009 | .63957 | .40401 | .67788 | .41811 | .71855 | .43240 | .76179 | 25 |
| 26 | .39032 | .64019 | .40424 | .67853 | .41835 | .71925 | .43264 | .76253 | 26 |
| 27 | .39055 | .64081 | .40448 | .67919 | .41859 | .71995 | .43287 | .76328 | 27 |
| 28 | .39078 | .64144 | .40471 | .67985 | .41882 | .72065 | .43311 | .76402 | 28 |
| 29 | .39101 | .64206 | .40494 | .68051 | .41906 | .72135 | .43335 | .76477 | 29 |
| 30 | .39124 | .64268 | .40518 | .68117 | .41930 | .72205 | .43359 | .76552 | 30 |
| 31 | .39147 | .64330 | .40541 | .68183 | .41953 | .72275 | .43383 | .76626 | 31 |
| 32 | .39170 | .64393 | .40565 | .68250 | .41977 | .72346 | .43407 | .76701 | 32 |
| 33 | .39193 | .64455 | .40588 | .68316 | .42001 | .72416 | .43431 | .76776 | 33 |
| 34 | .39216 | .64518 | .40611 | .68382 | .42024 | .72487 | .43455 | .76851 | 34 |
| 35 | .39239 | .64580 | .40635 | .68449 | .42048 | .72557 | .43479 | .76926 | 35 |
| 36 | .39262 | .64643 | .40658 | .68515 | .42072 | .72628 | .43503 | .77001 | 36 |
| 37 | .39286 | .64705 | .40682 | .68582 | .42096 | .72698 | .43527 | .77077 | 37 |
| 38 | .39309 | .64768 | .40705 | .68648 | .42119 | .72769 | .43551 | .77152 | 38 |
| 39 | .39332 | .64831 | .40728 | .68715 | .42143 | .72840 | .43575 | .77227 | 39 |
| 40 | .39355 | .64894 | .40752 | .68782 | .42167 | .72911 | .43599 | .77303 | 40 |
| 41 | .39378 | .64957 | .40775 | .68848 | .42191 | .72982 | .43623 | .77378 | 41 |
| 42 | .39401 | .65020 | .40799 | .68915 | .42214 | .73053 | .43647 | .77454 | 42 |
| 43 | .39424 | .65083 | .40822 | .68982 | .42238 | .73124 | .43671 | .77530 | 43 |
| 44 | .39447 | .65146 | .40846 | .69049 | .42262 | .73195 | .43695 | .77606 | 44 |
| 45 | 39471 | .65209 | .40869 | .69116 | .42285 | .73267 | .43720 | .77681 | 45 |
| 46 | .39494 | .65272 | .40893 | .69183 | .42309 | .73338 | .43744 | .77757 | 46 |
| 47 | .39517 | .65336 | .40916 | .69250 | .42333 | .73409 | .43768 | .77833 | 47 |
| 48 | .39540 | .65399 | .40939 | .69318 | .42357 | .73481 | .43792 | .77910 | 48 |
| 49 | .39563 | .65462 | .40963 | .69385 | .42381 | .73552 | .43816 | .77986 | 49 |
| 50 | .39586 | .65526 | .40986 | .69452 | .42404 | .73624 | .43840 | .78062 | 50 |
| 51 | .39610 | .65589 | .41010 | .69520 | .42428 | .73696 | .43864 | .78138 | 51 |
| 52 | .39633 | .65653 | .41033 | .69587 | .42452 | .73768 | .43888 | .78215 | 52 |
| 53 | .39656 | .65717 | .41057 | .69655 | .42476 | .73840 | .43912 | .78291 | 53 |
| 54 | .39679 | .65780 | .41080 | .69723 | .42499 | .73911 | .43936 | .78368 | 54 |
| 55 | .39702 | .65844 | .41104 | .69790 | .42523 | .73983 | .43960 | .78445 | 55 |
| 56 | .39726 | .65908 | .41127 | .69858 | .42547 | 74056 | .43984 | .78521 | 56 |
| 57 | .39749 | .65972 | .41151 | .69926 | .42571 | .74128 | .44008 | .78598 | 57 |
| 58 | .39772 | .66036 | .41174 | .69994 | .42595 | .74200 | .44032 | .78675 | 58 |
| 59 | .39795 | .66100 | .41198 | .70062 | .42619 | .74272 | .44057 | .78752 | 59 |
| 60 | .39819 | .66164 | .41221 | .70130 | .42642 | .74345 | .44081 | .78829 | 60 |

| ′ | 56° | | 57° | | 58° | | 59° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .44081 | .78829 | .45536 | .83608 | .47008 | .88708 | .48496 | .94160 | 0 |
| 1 | .44105 | .78906 | .45560 | .83690 | .47033 | .88796 | .48521 | .94254 | 1 |
| 2 | .44129 | .78984 | .45585 | .83773 | .47057 | .88884 | .48546 | .94349 | 2 |
| 3 | .44153 | .79061 | .45609 | .83855 | .47082 | .88972 | .48571 | .94443 | 3 |
| 4 | .44177 | .79138 | .45634 | .83938 | .47107 | .89060 | .48596 | .94537 | 4 |
| 5 | .44201 | .79216 | .45658 | .84020 | .47131 | .89148 | .48621 | .94632 | 5 |
| 6 | .44225 | .79293 | .45683 | .84103 | .47156 | .89237 | .48646 | .94726 | 6 |
| 7 | .44250 | .79371 | .45707 | .84186 | .47181 | .89325 | .48671 | .94821 | 7 |
| 8 | .44274 | .79449 | .45731 | .84269 | .47206 | .89414 | .48696 | .94916 | 8 |
| 9 | .44298 | .79527 | .45756 | .84352 | .47230 | .89503 | .48721 | .95011 | 9 |
| 10 | .44322 | .79604 | .45780 | .84435 | .47255 | .89591 | .48746 | .95106 | 10 |
| 11 | .44346 | .79682 | .45805 | .84518 | .47280 | .89680 | .48771 | .95201 | 11 |
| 12 | .44370 | .79761 | .45829 | .84601 | .47304 | .89769 | .48796 | .95296 | 12 |
| 13 | .44395 | .79839 | .45854 | .84685 | .47329 | .89858 | .48821 | .95392 | 13 |
| 14 | .44419 | .79917 | .45878 | .84768 | .47354 | .89948 | .48846 | .95487 | 14 |
| 15 | .44443 | .79995 | .45903 | .84852 | .47379 | .90037 | .48871 | .95583 | 15 |
| 16 | .44467 | .80074 | .45927 | .84935 | .47403 | .90126 | .48896 | .95678 | 16 |
| 17 | .44491 | .80152 | .45951 | .85019 | .47428 | .90216 | .48921 | .95774 | 17 |
| 18 | .44516 | .80231 | .45976 | .85103 | .47453 | .90305 | .48946 | .95870 | 18 |
| 19 | .44540 | .80309 | .46000 | .85187 | .47478 | .90395 | .48971 | .95966 | 19 |
| 20 | .44564 | .80388 | .46025 | .85271 | .47502 | .90485 | .48996 | .96062 | 20 |
| 21 | .44588 | .80467 | .46049 | .85355 | .47527 | .90575 | .49021 | .96158 | 21 |
| 22 | .44612 | .80546 | .46074 | .85439 | .47552 | .90665 | .49046 | .96255 | 22 |
| 23 | .44637 | .80625 | .46098 | .85523 | .47577 | .90755 | .49071 | .96351 | 23 |
| 24 | .44661 | .80704 | .46123 | .85608 | .47601 | .90845 | .49096 | .96448 | 24 |
| 25 | .44685 | .80783 | .46147 | .85692 | .47626 | .90935 | .49121 | .96544 | 25 |
| 26 | .44709 | .80862 | .46172 | .85777 | .47651 | .91026 | .49146 | .96641 | 26 |
| 27 | .44734 | .80942 | .46196 | .85861 | .47676 | .91116 | .49171 | .96738 | 27 |
| 28 | .44758 | .81021 | .46221 | .85946 | .47701 | .91207 | .49196 | .96835 | 28 |
| 29 | .44782 | .81101 | .46246 | .86031 | .47725 | .91297 | .49221 | .96932 | 29 |
| 30 | .44806 | .81180 | .46270 | .86116 | .47750 | .91388 | .49246 | .97029 | 30 |
| 31 | .44831 | .81260 | .46295 | .86201 | .47775 | .91479 | .49271 | .97127 | 31 |
| 32 | .44855 | .81340 | .46319 | .86286 | .47800 | .91570 | .49296 | .97224 | 32 |
| 33 | .44879 | .81419 | .46344 | .86371 | .47825 | .91661 | .49321 | .97322 | 33 |
| 34 | .44903 | .81499 | .46368 | .86457 | .47849 | .91752 | .49346 | .97420 | 34 |
| 35 | .44928 | .81579 | .46393 | .86542 | .47874 | .91844 | .49372 | .97517 | 35 |
| 36 | .44952 | .81659 | .46417 | .86627 | .47899 | .91935 | .49397 | .97615 | 36 |
| 37 | .44976 | .81740 | .46442 | .86713 | .47924 | .92027 | .49422 | .97713 | 37 |
| 38 | .45001 | .81820 | .46466 | .86799 | .47949 | .92118 | .49447 | .97811 | 38 |
| 39 | .45025 | .81900 | .46491 | .86885 | .47974 | .92210 | .49472 | .97910 | 39 |
| 40 | .45049 | .81981 | .46516 | .86990 | .47998 | .92302 | .49497 | .98008 | 40 |
| 41 | .45073 | .82061 | .46540 | .87056 | .48023 | .92394 | .49522 | .98107 | 41 |
| 42 | .45098 | .82142 | .46565 | .87142 | .48048 | .92486 | .49547 | .98205 | 42 |
| 43 | .45122 | .82222 | .46589 | .87229 | .48073 | .92578 | .49572 | .98304 | 43 |
| 44 | .45146 | .82303 | .46614 | .87315 | .48098 | .92670 | .49597 | .98403 | 44 |
| 45 | .45171 | .82384 | .46639 | .87401 | .48123 | .92762 | .49623 | .98502 | 45 |
| 46 | .45195 | .82465 | .46663 | .87488 | .48148 | .92855 | .49648 | .98601 | 46 |
| 47 | .45219 | .82546 | .46688 | .87574 | .48172 | .92947 | .49673 | .98700 | 47 |
| 48 | .45244 | .82627 | .46712 | .87661 | .48197 | .93040 | .49698 | .98799 | 48 |
| 49 | .45268 | .82709 | .46737 | .87748 | .48222 | .93133 | .49723 | .98899 | 49 |
| 50 | .45292 | .82790 | .46762 | .87834 | .48247 | .93226 | .49748 | .98998 | 50 |
| 51 | .45317 | .82871 | .46786 | .87921 | .48272 | .93319 | .49773 | .99098 | 51 |
| 52 | .45341 | .82953 | .46811 | .88008 | .48297 | .93412 | .49799 | .99198 | 52 |
| 53 | .45365 | .83034 | .46836 | .88095 | .48322 | .93505 | .49824 | .99298 | 53 |
| 54 | .45390 | .83116 | .46860 | .88183 | .48347 | .93598 | .49849 | .99398 | 54 |
| 55 | .45414 | .83198 | .46885 | .88270 | .48372 | .93692 | .49874 | .99498 | 55 |
| 56 | .45439 | .83280 | .46909 | .88357 | .48396 | .93785 | .49899 | .99598 | 56 |
| 57 | .45463 | .83362 | .46934 | .88445 | .48421 | .93879 | .49924 | .99698 | 57 |
| 58 | .45487 | .83444 | .46959 | .88532 | .48446 | .93973 | .49950 | .99799 | 58 |
| 59 | .45512 | .83526 | .46983 | .88620 | .48471 | .94066 | .49975 | .99899 | 59 |
| 60 | .45536 | .83608 | .47008 | .88708 | .48496 | .94160 | .50000 | 1.00000 | 60 |

| ′ | 60° |  | 61° |  | 62° |  | 63° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .50000 | 1.00000 | .51519 | 1.06267 | .53053 | 1.13005 | .54601 | 1.20269 | 0 |
| 1 | .50025 | 1.00101 | .51544 | 1.06375 | .53079 | 1.13122 | .54627 | 1.20395 | 1 |
| 2 | .50050 | 1.00202 | .51570 | 1.06483 | .53104 | 1.13239 | .54653 | 1.20521 | 2 |
| 3 | .50076 | 1.00303 | .51595 | 1.06592 | .53130 | 1.13356 | .54679 | 1.20647 | 3 |
| 4 | .50101 | 1.00404 | .51621 | 1.06701 | .53156 | 1.13473 | .54705 | 1.20773 | 4 |
| 5 | .50126 | 1.00505 | .51646 | 1.06809 | .53181 | 1.13590 | .54731 | 1.20900 | 5 |
| 6 | .50151 | 1.00607 | .51672 | 1.06918 | .53207 | 1.13707 | .54757 | 1.21026 | 6 |
| 7 | .50176 | 1.00708 | .51697 | 1.07027 | .53233 | 1.13825 | .54782 | 1.21153 | 7 |
| 8 | .50202 | 1.00810 | .51723 | 1.07137 | .53258 | 1.13942 | .54808 | 1.21280 | 8 |
| 9 | .50227 | 1.00912 | .51748 | 1.07246 | .53284 | 1.14060 | .54834 | 1.21407 | 9 |
| 10 | .50252 | 1.01014 | .51774 | 1.07356 | .53310 | 1.14178 | .54860 | 1.21535 | 10 |
| 11 | .50277 | 1.01116 | .51799 | 1.07465 | .53336 | 1.14296 | .54886 | 1.21662 | 11 |
| 12 | .50303 | 1.01218 | .51825 | 1.07575 | .53361 | 1.14414 | .54912 | 1.21790 | 12 |
| 13 | .50328 | 1.01320 | .51850 | 1.07685 | .53387 | 1.14533 | .54938 | 1.21918 | 13 |
| 14 | .50353 | 1.01422 | .51876 | 1.07795 | .53413 | 1.14651 | .54964 | 1.22045 | 14 |
| 15 | .50378 | 1.01525 | .51901 | 1.07905 | .53439 | 1.14770 | .54990 | 1.22174 | 15 |
| 16 | .50404 | 1.01628 | .51927 | 1.08015 | .53464 | 1.14889 | .55016 | 1.22302 | 16 |
| 17 | .50429 | 1.01730 | .51952 | 1.08126 | .53490 | 1.15008 | .55042 | 1.22430 | 17 |
| 18 | .50454 | 1.01833 | .51978 | 1.08236 | .53516 | 1.15127 | .55068 | 1.22559 | 18 |
| 19 | .50479 | 1.01936 | .52003 | 1.08347 | .53542 | 1.15246 | .55094 | 1.22688 | 19 |
| 20 | .50505 | 1.02039 | .52029 | 1.08458 | .53567 | 1.15366 | .55120 | 1.22817 | 20 |
| 21 | .50530 | 1.02143 | .52054 | 1.08569 | .53593 | 1.15485 | .55146 | 1.22946 | 21 |
| 22 | .50555 | 1.02246 | .52080 | 1.08680 | .53619 | 1.15605 | .55172 | 1.23075 | 22 |
| 23 | .50581 | 1.02349 | .52105 | 1.08791 | .53645 | 1.15725 | .55198 | 1.23205 | 23 |
| 24 | .50606 | 1.02453 | .52131 | 1.08903 | .53670 | 1.15845 | .55224 | 1.23334 | 24 |
| 25 | .50631 | 1.02557 | .52156 | 1.09014 | .53696 | 1.15965 | .55250 | 1.23464 | 25 |
| 26 | .50656 | 1.02661 | .52182 | 1.09126 | .53722 | 1.16085 | .55276 | 1.23594 | 26 |
| 27 | .50682 | 1.02765 | .52207 | 1.09238 | .53748 | 1.16206 | .55302 | 1.23724 | 27 |
| 28 | .50707 | 1.02869 | .52233 | 1.09350 | .53774 | 1.16326 | .55328 | 1.23855 | 28 |
| 29 | .50732 | 1.02973 | .52259 | 1.09462 | .53799 | 1.16447 | .55354 | 1.23985 | 29 |
| 30 | .50758 | 1.03077 | .52284 | 1.09574 | .53825 | 1.16568 | .55380 | 1.24116 | 30 |
| 31 | .50783 | 1.03182 | .52310 | 1.09686 | .53851 | 1.16689 | .55406 | 1.24247 | 31 |
| 32 | .50808 | 1.03286 | .52335 | 1.09799 | .53877 | 1.16810 | .55432 | 1.24378 | 32 |
| 33 | .50834 | 1.03391 | .52361 | 1.09911 | .53903 | 1.16932 | .55458 | 1.24509 | 33 |
| 34 | .50859 | 1.03496 | .52386 | 1.10024 | .53928 | 1.17053 | .55484 | 1.24640 | 34 |
| 35 | .50884 | 1.03601 | .52412 | 1.10137 | .53954 | 1.17175 | .55510 | 1.24772 | 35 |
| 36 | .50910 | 1.03706 | .52438 | 1.10250 | .53980 | 1.17297 | .55536 | 1.24903 | 36 |
| 37 | .50935 | 1.03811 | .52463 | 1.10363 | .54006 | 1.17419 | .55563 | 1.25035 | 37 |
| 38 | .50960 | 1.03916 | .52489 | 1.10477 | .54032 | 1.17541 | .55589 | 1.25167 | 38 |
| 39 | .50986 | 1.04022 | .52514 | 1.10590 | .54058 | 1.17663 | .55615 | 1.25300 | 39 |
| 40 | .51011 | 1.04128 | .52540 | 1.10704 | .54083 | 1.17786 | .55641 | 1.25432 | 40 |
| 41 | .51036 | 1.04233 | .52566 | 1.10817 | .54109 | 1.17909 | .55667 | 1.25565 | 41 |
| 42 | .51062 | 1.04339 | .52591 | 1.10931 | .54135 | 1.18031 | .55693 | 1.25697 | 42 |
| 43 | .51087 | 1.04445 | .52617 | 1.11045 | .54161 | 1.18154 | .55719 | 1.25830 | 43 |
| 44 | .51113 | 1.04551 | .52642 | 1.11159 | .54187 | 1.18277 | .55745 | 1.25963 | 44 |
| 45 | .51138 | 1.04658 | .52668 | 1.11274 | .54213 | 1.18401 | .55771 | 1.26097 | 45 |
| 46 | .51163 | 1.04764 | .52694 | 1.11388 | .54238 | 1.18524 | .55797 | 1.26230 | 46 |
| 47 | .51189 | 1.04870 | .52719 | 1.11503 | .54264 | 1.18648 | .55823 | 1.26364 | 47 |
| 48 | .51214 | 1.04977 | .52745 | 1.11617 | .54290 | 1.18772 | .55849 | 1.26498 | 48 |
| 49 | .51239 | 1.05084 | .52771 | 1.11732 | .54316 | 1.18895 | .55876 | 1.26632 | 49 |
| 50 | .51265 | 1.05191 | .52796 | 1.11847 | .54342 | 1.19019 | .55902 | 1.26766 | 50 |
| 51 | .51290 | 1.05298 | .52822 | 1.11963 | .54368 | 1.19144 | .55928 | 1.26900 | 51 |
| 52 | .51316 | 1.05405 | .52848 | 1.12078 | .54394 | 1.19268 | .55954 | 1.27035 | 52 |
| 53 | .51341 | 1.05512 | .52873 | 1.12193 | .54420 | 1.19393 | .55980 | 1.27169 | 53 |
| 54 | .51366 | 1.05619 | .52899 | 1.12309 | .54446 | 1.19517 | .56006 | 1.27304 | 54 |
| 55 | .51392 | 1.05727 | .52924 | 1.12425 | .54471 | 1.19642 | .56032 | 1.27439 | 55 |
| 56 | .51417 | 1.05835 | .52950 | 1.12540 | .54497 | 1.19767 | .56058 | 1.27574 | 56 |
| 57 | .51443 | 1.05942 | .52976 | 1.12657 | .54523 | 1.19892 | .56084 | 1.27710 | 57 |
| 58 | .51468 | 1.06050 | .53001 | 1.12773 | .54549 | 1.20018 | .56111 | 1.27845 | 58 |
| 59 | .51494 | 1.06158 | .53027 | 1.12889 | .54575 | 1.20143 | .56137 | 1.27981 | 59 |
| 60 | .51519 | 1.06267 | .53053 | 1.13005 | .54601 | 1.20269 | .56163 | 1.28117 | 60 |

| ′ | 64° | | 65° | | 66° | | 67° | | |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .56163 | 1.28117 | .57738 | 1.36620 | .59326 | 1.45859 | .60927 | 1.55930 | 0 |
| 1 | .56189 | 1.28253 | .57765 | 1.36768 | .59353 | 1.46020 | .60954 | 1.56106 | 1 |
| 2 | .56215 | 1.28390 | .57791 | 1.36916 | .59379 | 1.46181 | .60980 | 1.56282 | 2 |
| 3 | .56241 | 1.28526 | .57817 | 1.37064 | .59406 | 1.46342 | .61007 | 1.56458 | 3 |
| 4 | .56267 | 1.28663 | .57844 | 1.37212 | .59433 | 1.46504 | .61034 | 1.56634 | 4 |
| 5 | .56294 | 1.28800 | .57870 | 1.37361 | .59459 | 1.46665 | .61061 | 1.56811 | 5 |
| 6 | .56320 | 1.28937 | .57896 | 1.37509 | .59486 | 1.46827 | .61088 | 1.56988 | 6 |
| 7 | .56346 | 1.29074 | .57923 | 1.37658 | .59512 | 1.46989 | .61114 | 1.57165 | 7 |
| 8 | .56372 | 1.29211 | .57949 | 1.37808 | .59539 | 1.47152 | .61141 | 1.57342 | 8 |
| 9 | .56398 | 1.29349 | .57976 | 1.37957 | .59566 | 1.47314 | .61168 | 1.57520 | 9 |
| 10 | .56425 | 1.29487 | .58002 | 1.38107 | .59592 | 1.47477 | .61195 | 1.57698 | 10 |
| 11 | .56451 | 1.29625 | .58028 | 1.38256 | .59619 | 1.47640 | .61222 | 1.57876 | 11 |
| 12 | .56477 | 1·29763 | .58055 | 1.38406 | .59645 | 1.47804 | .61248 | 1.58054 | 12 |
| 13 | .56503 | 1.29901 | .58081 | 1.38556 | .59672 | 1.47967 | .61275 | 1.58233 | 13 |
| 14 | .56529 | 1.30040 | .58108 | 1.38707 | .59699 | 1.48131 | .61302 | 1.58412 | 14 |
| 15 | .56555 | 1.30179 | .58134 | 1.38857 | .59725 | 1.48295 | .61329 | 1.58591 | 15 |
| 16 | .56582 | 1.30318 | .58160 | 1.39008 | .59752 | 1.48459 | .61356 | 1.58771 | 16 |
| 17 | .56608 | 1.30457 | .58187 | 1.39159 | .59779 | 1.48624 | .61383 | 1.58950 | 17 |
| 18 | .56634 | 1.30596 | .58213 | 1.39311 | .59805 | 1.48789 | .61409 | 1.59130 | 18 |
| 19 | .56660 | 1.30735 | .58240 | 1.39462 | .59832 | 1.48954 | .61436 | 1.59311 | 19 |
| 20 | .56687 | 1.30875 | .58266 | 1.39614 | .59859 | 1.49119 | .61463 | 1.59491 | 20 |
| 21 | .56713 | 1.31015 | .58293 | 1.39766 | .59885 | 1.49284 | .61490 | 1.59672 | 21 |
| 22 | .56739 | 1.31155 | .58319 | 1.39918 | .59912 | 1.49450 | .61517 | 1.59853 | 22 |
| 23 | .56765 | 1.31295 | .58345 | 1.40070 | .59938 | 1.49616 | .61544 | 1.60035 | 23 |
| 24 | .56791 | 1.31436 | .58372 | 1.40222 | .59965 | 1.49782 | .61570 | 1.60217 | 24 |
| 25 | .56818 | 1.31576 | .58398 | 1.40375 | .59992 | 1.49948 | .61597 | 1.60399 | 25 |
| 26 | .56844 | 1.31717 | .58425 | 1.40528 | .60018 | 1.50115 | .61624 | 1.60581 | 26 |
| 27 | .56870 | 1.31858 | .58451 | 1.40681 | .60045 | 1.50282 | .61651 | 1.60763 | 27 |
| 28 | .56896 | 1.31999 | .58478 | 1.40835 | .60072 | 1.50449 | .61678 | 1.60946 | 28 |
| 29 | .56923 | 1.32140 | .58504 | 1.40988 | .60098 | 1.50617 | .61705 | 1.61129 | 29 |
| 30 | .56949 | 1.32282 | .58531 | 1.41142 | .60125 | 1.50784 | .61732 | 1.61313 | 30 |
| 31 | .56975 | 1.32424 | .58557 | 1.41296 | .60152 | 1.50952 | .61759 | 1.61496 | 31 |
| 32 | .57001 | 1.32566 | .58584 | 1.41450 | .60178 | 1.51120 | .61785 | 1.61680 | 32 |
| 33 | .57028 | 1.32708 | .58610 | 1.41605 | .60205 | 1.51289 | .61812 | 1.61864 | 33 |
| 34 | .57054 | 1.32850 | .58637 | 1.41760 | .60232 | 1.51457 | .61839 | 1.62049 | 34 |
| 35 | .57080 | 1.32993 | .58663 | 1.41914 | .60259 | 1.51626 | .61866 | 1.62234 | 35 |
| 36 | .57106 | 1.33135 | .58690 | 1.42070 | .60285 | 1.51795 | .61893 | 1.62419 | 36 |
| 37 | .57133 | 1.33278 | .58716 | 1.42225 | .60312 | 1.51965 | .61920 | 1.62604 | 37 |
| 38 | .57159 | 1.33422 | .58743 | 1.42380 | .60339 | 1.52134 | .61947 | 1.62790 | 38 |
| 39 | .57185 | 1.33565 | .58769 | 1.42536 | .60365 | 1.52304 | .61974 | 1.62976 | 39 |
| 40 | .57212 | 1.33708 | .58796 | 1.42692 | .60392 | 1.52474 | .62001 | 1.63162 | 40 |
| 41 | .57238 | 1.33852 | .58822 | 1.42848 | .60419 | 1.52645 | .62027 | 1.63348 | 41 |
| 42 | .57264 | 1.33996 | .58849 | 1.43005 | .60445 | 1.52815 | .62054 | 1.63535 | 42 |
| 43 | .57291 | 1.34140 | .58875 | 1.43162 | .60472 | 1.52986 | .62081 | 1.63722 | 43 |
| 44 | .57317 | 1.34284 | .58902 | 1.43318 | .60499 | 1.53157 | .62108 | 1.63909 | 44 |
| 45 | .57343 | 1.34429 | .58928 | 1.43476 | .60526 | 1.53329 | .62135 | 1.64097 | 45 |
| 46 | .57369 | 1.34573 | .58955 | 1.43633 | .60552 | 1.53500 | .62162 | 1.64285 | 46 |
| 47 | .57396 | 1.34718 | .58981 | 1.43790 | .60579 | 1.53672 | .62189 | 1.64473 | 47 |
| 48 | .57422 | 1.34863 | .59008 | 1.43948 | .60606 | 1.53845 | .62216 | 1.64662 | 48 |
| 49 | .57448 | 1.35009 | .59034 | 1.44106 | .60633 | 1.54017 | .62243 | 1.64851 | 49 |
| 50 | .57475 | 1.35154 | .59061 | 1.44264 | .60659 | 1.54190 | .62270 | 1.65040 | 50 |
| 51 | .57501 | 1.35300 | .59087 | 1.44423 | .60686 | 1.54363 | .62297 | 1.65229 | 51 |
| 52 | .57527 | 1.35446 | .59114 | 1.44582 | .60713 | 1.54536 | .62324 | 1.65419 | 52 |
| 53 | .57554 | 1.35592 | .59140 | 1.44741 | .60740 | 1.54709 | .62351 | 1.65609 | 53 |
| 54 | .57580 | 1.35738 | .59167 | 1.44900 | .60766 | 1.54883 | .62378 | 1.65799 | 54 |
| 55 | .57606 | 1.35885 | .59194 | 1.45059 | .60793 | 1.55057 | .62405 | 1.65989 | 55 |
| 56 | .57633 | 1.36031 | .59220 | 1.45219 | .60820 | 1.55231 | .62431 | 1.66180 | 56 |
| 57 | .57659 | 1.36178 | .59247 | 1.45378 | .60847 | 1.55405 | .62458 | 1.66371 | 57 |
| 58 | .57685 | 1.36325 | .59273 | 1.45539 | .60873 | 1.55580 | .62485 | 1.66563 | 58 |
| 59 | .57712 | 1.36473 | .59300 | 1.45699 | .60900 | 1.55755 | .62512 | 1.66755 | 59 |
| 60 | .57738 | 1.36620 | .59326 | 1.45859 | .60927 | 1.55930 | .62539 | 1.66947 | 60 |

| ′ | 68° |  | 69° |  | 70° |  | 71° |  | ′ |
|---|---|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .62539 | 1.66947 | .64163 | 1.79043 | .65798 | 1.92380 | .67443 | 2.07155 | 0 |
| 1 | .62566 | 1.67139 | .64190 | 1.79254 | .65825 | 1.92614 | .67471 | 2.07415 | 1 |
| 2 | .62593 | 1.67332 | .64218 | 1.79466 | .65853 | 1.92849 | .67498 | 2.07675 | 2 |
| 3 | .62620 | 1.67525 | .64245 | 1.79679 | .65880 | 1.93083 | .67526 | 2.07936 | 3 |
| 4 | .62647 | 1.67718 | .64272 | 1.79891 | .65907 | 1.93318 | .67553 | 2.08197 | 4 |
| 5 | .62674 | 1.67911 | .64299 | 1.80104 | .65935 | 1.93554 | .67581 | 2.08459 | 5 |
| 6 | .62701 | 1.68105 | .64326 | 1.80318 | .65962 | 1.93790 | .67608 | 2.08721 | 6 |
| 7 | .62728 | 1.68299 | .64353 | 1.80531 | .65989 | 1.94026 | .67636 | 2.08983 | 7 |
| 8 | .62755 | 1.68494 | .64381 | 1.80746 | .66017 | 1.94263 | .67663 | 2.09246 | 8 |
| 9 | .62782 | 1.68689 | .64408 | 1.80960 | .66044 | 1.94500 | .67691 | 2.09510 | 9 |
| 10 | .62809 | 1.68884 | .64435 | 1.81175 | .66071 | 1.94737 | .67718 | 2.09774 | 10 |
| 11 | .62836 | 1 69079 | .64462 | 1.81390 | .66099 | 1.94975 | .67746 | 2.10038 | 11 |
| 12 | .62863 | 1.69275 | .64489 | 1.81605 | .66126 | 1.95213 | .67773 | 2.10303 | 12 |
| 13 | .62890 | 1.69471 | .64517 | 1.81821 | .66154 | 1.95452 | .67801 | 2.10568 | 13 |
| 14 | .62917 | 1.69667 | .64544 | 1.82037 | .66181 | 1.95691 | .67829 | 2.10834 | 14 |
| 15 | .62944 | 1.69864 | .64571 | 1.82254 | .66208 | 1.95931 | .67856 | 2.11101 | 15 |
| 16 | .62971 | 1.70061 | .64598 | 1.82471 | .66236 | 1.96171 | .67884 | 2.11367 | 16 |
| 17 | .62998 | 1.70258 | .64625 | 1.82688 | .66263 | 1.96411 | .67911 | 2.11635 | 17 |
| 18 | .63025 | 1.70455 | .64653 | 1.82906 | .66290 | 1.96652 | .67939 | 2.11903 | 18 |
| 19 | .63052 | 1.70653 | .64680 | 1.83124 | .66318 | 1.96893 | .67966 | 2.12171 | 19 |
| 20 | .63079 | 1.70851 | .64707 | 1.83342 | .66345 | 1.97135 | .67994 | 2.12440 | 20 |
| 21 | .63106 | 1.71050 | .64734 | 1.83561 | .66373 | 1.97377 | .68021 | 2.12709 | 21 |
| 22 | .63133 | 1.71249 | .64761 | 1.83780 | .66400 | 1.97619 | .68049 | 2.12979 | 22 |
| 23 | .63161 | 1.71448 | .64789 | 1.83999 | .66427 | 1.97862 | .68077 | 2.13249 | 23 |
| 24 | .63188 | 1.71647 | .64816 | 1.84219 | .66455 | 1.98106 | .68104 | 2.13520 | 24 |
| 25 | .63215 | 1.71847 | .64843 | 1.84439 | .66482 | 1.98349 | .68132 | 2.13791 | 25 |
| 26 | .63242 | 1.72047 | .64870 | 1.84659 | .66510 | 1.96594 | .68159 | 2.14063 | 26 |
| 27 | .63269 | 1.72247 | .64898 | 1.84880 | .66537 | 1.98838 | .68187 | 2.14335 | 27 |
| 28 | .63296 | 1.72448 | .64925 | 1.85102 | .66564 | 1.99083 | .68214 | 2.14608 | 28 |
| 29 | .63323 | 1.72649 | .64952 | 1.85323 | .66592 | 1.99329 | .68242 | 2.14881 | 29 |
| 30 | .63350 | 1.72850 | .64979 | 1.85545 | .66619 | 1.99574 | .68270 | 2.15155 | 30 |
| 31 | .63377 | 1.73052 | .65007 | 1.85767 | .66647 | 1.99821 | .68297 | 2.15429 | 31 |
| 32 | .63404 | 1.73254 | .65034 | 1.85990 | .66674 | 2.00067 | .68325 | 2.15704 | 32 |
| 33 | .63431 | 1.73456 | .65061 | 1.86213 | .66702 | 2.00315 | .68352 | 2.15979 | 33 |
| 34 | .63458 | 1.73659 | .65088 | 1.86437 | .66729 | 2.00562 | .68380 | 2.16255 | 34 |
| 35 | .63485 | 1.73862 | .65116 | 1.86661 | .66756 | 2.00810 | .68408 | 2.16531 | 35 |
| 36 | .63512 | 1.74065 | .65143 | 1.86885 | .66784 | 2.01059 | .68435 | 2.16808 | 36 |
| 37 | .63539 | 1.74269 | .65170 | 1.87109 | .66811 | 2.01308 | .68463 | 2.17085 | 37 |
| 38 | .63566 | 1.74473 | .65197 | 1.87334 | .66839 | 2.01557 | .68490 | 2.17363 | 38 |
| 39 | .63594 | 1.74677 | .65225 | 1.87560 | .66866 | 2.01807 | .68518 | 2.17641 | 39 |
| 40 | .63621 | 1.74881 | .65252 | 1.87785 | .66894 | 2.02057 | .68546 | 2.17920 | 40 |
| 41 | .63648 | 1.75086 | .65279 | 1.88011 | .66921 | 2.02308 | .68573 | 2.18199 | 41 |
| 42 | .63675 | 1.75292 | .65306 | 1.88238 | .66949 | 2.02559 | .68601 | 2.18479 | 42 |
| 43 | .63702 | 1.75497 | .65334 | 1.88465 | .66976 | 2.02810 | .68628 | 2.18759 | 43 |
| 44 | .63729 | 1.75703 | .65361 | 1.88692 | .67003 | 2.03062 | .68656 | 2.19040 | 44 |
| 45 | .63756 | 1.75909 | .65388 | 1.88920 | .67031 | 2.03315 | .68684 | 2.19322 | 45 |
| 46 | .63783 | 1.76116 | .65416 | 1.89148 | .67058 | 2.03568 | .68711 | 2.19604 | 46 |
| 47 | .63810 | 1.76323 | .65443 | 1.89376 | .67086 | 2.03821 | .68739 | 2.19886 | 47 |
| 48 | .63838 | 1.76530 | .65470 | 1.89605 | .67113 | 2.04075 | .68767 | 2.20169 | 48 |
| 49 | .63865 | 1.76737 | .65497 | 1.89834 | .67141 | 2.04329 | .68794 | 2.20453 | 49 |
| 50 | .63892 | 1.76945 | .65525 | 1.90063 | .67168 | 2.04584 | .68822 | 2.20737 | 50 |
| 51 | .63919 | 1.77154 | .65552 | 1.90293 | .67196 | 2.04839 | .68849 | 2.21021 | 51 |
| 52 | .63946 | 1.77362 | .65579 | 1.90524 | .67223 | 2.05094 | .68877 | 2.21306 | 52 |
| 53 | .63973 | 1.77571 | .65607 | 1.90754 | .67251 | 2.05350 | .68905 | 2.21592 | 53 |
| 54 | .64000 | 1 77780 | .65634 | 1.90986 | .67278 | 2.05607 | .68932 | 2.21878 | 54 |
| 55 | .64027 | 1.77990 | .65661 | 1.91217 | .67306 | 2.05864 | .68960 | 2.22165 | 55 |
| 56 | .64055 | 1.78200 | .65689 | 1.91449 | .67333 | 2.06121 | .68988 | 2.22452 | 56 |
| 57 | .64082 | 1.78410 | .65716 | 1.91681 | .67361 | 2.06379 | .69015 | 2.22740 | 57 |
| 58 | .64109 | 1.78621 | .65743 | 1.91914 | .67388 | 2 06637 | .69043 | 2.23028 | 58 |
| 59 | .64136 | 1.78832 | .65771 | 1.92147 | .67416 | 2.06896 | .69071 | 2.23317 | 59 |
| 60 | .64163 | 1.79043 | .65798 | 1.92380 | .67443 | 2.07155 | .69098 | 2.23607 | 60 |

| ′ | 72° | | 73° | | 74° | | 75° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .69098 | 2.23607 | .70763 | 2.42030 | .72436 | 2.62796 | .74118 | 2.86370 | 0 |
| 1 | .69126 | 2.23897 | .70791 | 2.42356 | .72464 | 2.63164 | .74146 | 2.86790 | 1 |
| 2 | .69154 | 2.24187 | .70818 | 2.42683 | .72492 | 2.63533 | .74174 | 2.87211 | 2 |
| 3 | .69181 | 2.24478 | .70846 | 2.43010 | .72520 | 2.63903 | .74202 | 2.87633 | 3 |
| 4 | .69209 | 2.24770 | .70874 | 2.43337 | .72548 | 2.64274 | .74231 | 2.88056 | 4 |
| 5 | .69237 | 2.25062 | .70902 | 2.43666 | .72576 | 2.64645 | .74259 | 2.88479 | 5 |
| 6 | 69264 | 2.25355 | .70930 | 2.43995 | .72604 | 2.65018 | .74287 | 2.88904 | 6 |
| 7 | .69292 | 2.25648 | .70958 | 2.44324 | .72632 | 2.65391 | .74315 | 2.89330 | 7 |
| 8 | .69320 | 2.25942 | .70985 | 2.44655 | .72660 | 2.65765 | .74343 | 2.89756 | 8 |
| 9 | .69347 | 2 26237 | .71013 | 2.44986 | .72688 | 2.66140 | .74371 | 2.90184 | 9 |
| 10 | .69375 | 2.26531 | .71041 | 2.45317 | .72716 | 2.66515 | .74399 | 2.90613 | 10 |
| 11 | .69403 | 2.26827 | .71069 | 2.45650 | .72744 | 2.66892 | .74427 | 2.91042 | 11 |
| 12 | .69430 | 2.27123 | .71097 | 2.45983 | .72772 | 2.67269 | .74455 | 2.91473 | 12 |
| 13 | .69458 | 2.27420 | .71125 | 2.46316 | .72800 | 2.67647 | .74484 | 2.91904 | 13 |
| 14 | .69486 | 2.27717 | .71153 | 2.46651 | .72828 | 2.68025 | .74512 | 2.92337 | 14 |
| 15 | .69514 | 2.28015 | .71180 | 2.46986 | .72856 | 2.68405 | .74540 | 2.92770 | 15 |
| 16 | .69541 | 2.28313 | .71208 | 2.47321 | .72884 | 2.68785 | .74568 | 2.93204 | 16 |
| 17 | .69569 | 2.28612 | .71236 | 2.47658 | .72912 | 2.69167 | .74596 | 2.93640 | 17 |
| 18 | .69597 | 2.28912 | .71264 | 2.47995 | .72940 | 2.69549 | .74624 | 2.94076 | 18 |
| 19 | .69624 | 2.29212 | .71292 | 2.48333 | .72968 | 2.69931 | .74652 | 2.94514 | 19 |
| 20 | .69652 | 2.29512 | .71320 | 2.48671 | .72996 | 2.70315 | .74680 | 2.94952 | 20 |
| 21 | .69680 | 2.29814 | .71348 | 2.49010 | .73024 | 2.70700 | .74709 | 2.95392 | 21 |
| 22 | .69708 | 2.30115 | .71375 | 2.49350 | .73052 | 2.71085 | .74737 | 2.95832 | 22 |
| 23 | .69735 | 2.30418 | .71403 | 2.49691 | .73080 | 2.71471 | .74765 | 2.96274 | 23 |
| 24 | .69763 | 2.30721 | .71431 | 2.50032 | .73108 | 2.71858 | .74793 | 2.96716 | 24 |
| 25 | .69791 | 2.31024 | .71459 | 2.50374 | .73136 | 2.72246 | .74821 | 2.97160 | 25 |
| 26 | .69818 | 2.31328 | .71487 | 2.50716 | .73164 | 2.72635 | .74849 | 2.97604 | 26 |
| 27 | .69846 | 2.31633 | .71515 | 2.51060 | .73192 | 2.73024 | .74878 | 2.98050 | 27 |
| 28 | .69874 | 2.31939 | .71543 | 2.51404 | .73220 | 2.73414 | .74906 | 2.98497 | 28 |
| 29 | .69902 | 2.32244 | .71571 | 2.51748 | .73248 | 2.73806 | .74934 | 2.98944 | 29 |
| 30 | .69929 | 2.32551 | .71598 | 2.52094 | .73276 | 2.74198 | .74962 | 2.99393 | 30 |
| 31 | .69957 | 2.32858 | .71626 | 2.52440 | .73304 | 2.74591 | .74990 | 2.99843 | 31 |
| 32 | .69985 | 2.33166 | .71654 | 2.52787 | .73332 | 2.74984 | .75018 | 3.00293 | 32 |
| 33 | .70013 | 2.33474 | .71682 | 2.53134 | .73360 | 2.75379 | .75047 | 3.00745 | 33 |
| 34 | .70040 | 2.33783 | .71710 | 2.53482 | .73388 | 2.75775 | .75075 | 3.01198 | 34 |
| 35 | .70068 | 2.34092 | .71738 | 2.53831 | .73416 | 2.76171 | .75103 | 3.01652 | 35 |
| 36 | .70096 | 2.34403 | .71766 | 2.54181 | .73444 | 2.76568 | .75131 | 3.02107 | 36 |
| 37 | .70124 | 2.34713 | .71794 | 2.54531 | .73472 | 2.76966 | .75159 | 3.02563 | 37 |
| 38 | .70151 | 2.35025 | .71822 | 2.54883 | .73500 | 2.77365 | .75187 | 3.03020 | 38 |
| 39 | .70179 | 2.35336 | .71850 | 2.55235 | .73529 | 2.77765 | .75216 | 3.03479 | 39 |
| 40 | .70207 | 2.35649 | .71877 | 2.55587 | .73557 | 2.78166 | .75244 | 3.03938 | 40 |
| 41 | .70235 | 2.35962 | .71905 | 2.55940 | .73585 | 2.78568 | .75272 | 3.04398 | 41 |
| 42 | .70263 | 2.36276 | .71933 | 2.56294 | .73613 | 2.78970 | .75300 | 3.04860 | 42 |
| 43 | .70290 | 2.36590 | .71961 | 2.56649 | .73641 | 2.79374 | .75328 | 3.05322 | 43 |
| 44 | .70318 | 2.36905 | .71989 | 2.57005 | .73669 | 2.79778 | .75356 | 3.05786 | 44 |
| 45 | .70346 | 2.37221 | .72017 | 2.57361 | .73697 | 2.80183 | .75385 | 3.06251 | 45 |
| 46 | .70374 | 2.37537 | .72045 | 2.57718 | .73725 | 2.80589 | .75413 | 3.06717 | 46 |
| 47 | .70401 | 2.37854 | .72073 | 2.58076 | .73753 | 2.80996 | .75441 | 3.07184 | 47 |
| 48 | .70429 | 2.38171 | .72101 | 2.58434 | .73781 | 2.81404 | .75469 | 3.07652 | 48 |
| 49 | .70457 | 2.38489 | .72129 | 2.58794 | .73809 | 2.81813 | .75497 | 3.08121 | 49 |
| 50 | .70485 | 2.38808 | .72157 | 2.59154 | .73837 | 2.82223 | .75526 | 3.08591 | 50 |
| 51 | .70513 | 2.39128 | .72185 | 2.59514 | .73865 | 2.82633 | .75554 | 3.09063 | 51 |
| 52 | .70540 | 2.39448 | .72213 | 2.59876 | .73893 | 2.83045 | .75582 | 3.09535 | 52 |
| 53 | .70568 | 2.39768 | .72241 | 2.60238 | .73921 | 2.83457 | .75610 | 3.10009 | 53 |
| 54 | .70596 | 2.40089 | .72269 | 2.60601 | .73950 | 2.83871 | .75639 | 3.10484 | 54 |
| 55 | .70624 | 2.40411 | .72296 | 2.60965 | .73978 | 2.84285 | .75667 | 3.10960 | 55 |
| 56 | .70652 | 2.40734 | .72324 | 2.61330 | .74006 | 2.84700 | .75695 | 3.11437 | 56 |
| 57 | .70679 | 2.41057 | .72352 | 2.61695 | .74034 | 2.85116 | .75723 | 3.11915 | 57 |
| 58 | .70707 | 2.41381 | .72380 | 2.62061 | .74062 | 2.85533 | .75751 | 3.12394 | 58 |
| 59 | .70735 | 2.41705 | .72408 | 2.62428 | .74090 | 2.85951 | .75780 | 3.12875 | 59 |
| 60 | .70763 | 2.42030 | .72436 | 2.62796 | .74118 | 2.86370 | .75808 | 3.13357 | 60 |

| ′ | 76° | | 77° | | 78° | | 79° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .75808 | 3.13357 | .77505 | 3.44541 | .79209 | 3.80973 | .80919 | 4.24084 | 0 |
| 1 | .75836 | 3.13839 | .77533 | 3.45102 | .79237 | 3.81633 | .80948 | 4.24870 | 1 |
| 2 | .75864 | 3.14323 | .77562 | 3.45664 | .79266 | 3.82294 | .80976 | 4.25658 | 2 |
| 3 | .75892 | 3.14809 | .77590 | 3.46228 | .79294 | 3.82956 | .81005 | 4.26448 | 3 |
| 4 | .75921 | 3.15295 | .77618 | 3.46793 | .79323 | 3.83621 | .81033 | 4.27241 | 4 |
| 5 | .75949 | 3.15782 | .77647 | 3.47360 | .79351 | 3.84288 | .81062 | 4.28036 | 5 |
| 6 | .75977 | 3.16271 | .77675 | 3.47928 | .79380 | 3.84956 | .81090 | 4.28833 | 6 |
| 7 | .76005 | 3.16761 | .77703 | 3.48498 | .79408 | 3.85627 | .81119 | 4.29634 | 7 |
| 8 | .76034 | 3.17252 | .77732 | 3.49069 | .79437 | 3.86299 | .81148 | 4.30436 | 8 |
| 9 | .76062 | 3.17744 | .77760 | 3.49642 | .79465 | 3.86973 | .81176 | 4.31241 | 9 |
| 10 | .76090 | 3.18238 | .77788 | 3.50216 | .79493 | 3.87649 | .81205 | 4.32049 | 10 |
| 11 | .76118 | 3.18733 | .77817 | 3.50791 | .79522 | 3.88327 | .81233 | 4.32859 | 11 |
| 12 | .76147 | 3.19228 | .77845 | 3.51368 | .79550 | 3.89007 | .81262 | 4.33671 | 12 |
| 13 | .76175 | 3.19725 | .77874 | 3.51947 | .79579 | 3.89689 | .81290 | 4.34486 | 13 |
| 14 | .76203 | 3.20224 | .77902 | 3.52527 | .79607 | 3.90373 | .81319 | 4.35304 | 14 |
| 15 | .76231 | 3.20723 | .77930 | 3.53109 | .79636 | 3.91058 | .81348 | 4.36124 | 15 |
| 16 | .76260 | 3.21224 | .77959 | 3.53692 | .79664 | 3.91746 | .81376 | 4.36947 | 16 |
| 17 | .76288 | 3.21726 | .77987 | 3.54277 | .79693 | 3.92436 | .81405 | 4.37772 | 17 |
| 18 | .76316 | 3.22229 | .78015 | 3.54863 | .79721 | 3.93128 | .81433 | 4.38600 | 18 |
| 19 | .76344 | 3.22734 | .78044 | 3.55451 | .79750 | 3.93821 | .81462 | 4.39430 | 19 |
| 20 | .76373 | 3.23239 | .78072 | 3.56041 | .79778 | 3.94517 | .81491 | 4.40263 | 20 |
| 21 | .76401 | 3.23746 | .78101 | 3.56632 | .79807 | 3.95215 | .81519 | 4.41099 | 21 |
| 22 | .76429 | 3.24255 | .78129 | 3.57224 | .79835 | 3.95914 | .81548 | 4.41937 | 22 |
| 23 | .76458 | 3.24764 | .78157 | 3.57819 | .79864 | 3.96616 | .81576 | 4.42778 | 23 |
| 24 | .76486 | 3.25275 | .78186 | 3.58414 | .79892 | 3.97320 | .81605 | 4.43622 | 24 |
| 25 | .76514 | 3.25787 | .78214 | 3.59012 | .79921 | 3.98025 | .81633 | 4.44468 | 25 |
| 26 | .76542 | 3.26300 | .78242 | 3.59611 | .79949 | 3.98733 | .81662 | 4.45317 | 26 |
| 27 | .76571 | 3.26814 | .78271 | 3.60211 | .79978 | 3.99443 | .81691 | 4.46169 | 27 |
| 28 | .76599 | 3.27330 | .78299 | 3.60813 | .80006 | 4.00155 | .81719 | 4.47023 | 28 |
| 29 | .76627 | 3.27847 | .78328 | 3.61417 | .80035 | 4.00869 | .81748 | 4.47881 | 29 |
| 30 | .76655 | 3.28366 | .78356 | 3.62023 | .80063 | 4.01585 | .81776 | 4.48740 | 30 |
| 31 | .76684 | 3.28885 | .78384 | 3.62630 | .80092 | 4.02303 | .81805 | 4.49603 | 31 |
| 32 | .76712 | 3.29406 | .78413 | 3.63238 | .80120 | 4.03024 | .81834 | 4.50468 | 32 |
| 33 | .76740 | 3.29929 | .78441 | 3.63849 | .80149 | 4.03746 | .81862 | 4.51337 | 33 |
| 34 | .76769 | 3.30452 | .78470 | 3.64461 | .80177 | 4.04471 | .81891 | 4.52208 | 34 |
| 35 | .76797 | 3.30977 | .78498 | 3.65074 | .80206 | 4.05197 | .81919 | 4.53081 | 35 |
| 36 | .76825 | 3.31503 | .78526 | 3.65690 | .80234 | 4.05926 | .81948 | 4.53958 | 36 |
| 37 | .76854 | 3.32031 | .78555 | 3.66307 | .80263 | 4.06657 | .81977 | 4.54837 | 37 |
| 38 | .76882 | 3.32560 | .78583 | 3.66925 | .80291 | 4.07390 | .82005 | 4.55720 | 38 |
| 39 | .76910 | 3.33090 | .78612 | 3.67545 | .80320 | 4.08125 | .82034 | 4.56605 | 39 |
| 40 | .76938 | 3.33622 | .78640 | 3.68167 | .80348 | 4.08863 | .82063 | 4.57493 | 40 |
| 41 | .76967 | 3.34154 | .78669 | 3.68791 | .80377 | 4.09602 | .82091 | 4.58383 | 41 |
| 42 | .76995 | 3.34689 | .78697 | 3.69417 | .80405 | 4.10344 | .82120 | 4.50277 | 42 |
| 43 | .77023 | 3.35224 | .78725 | 3.70044 | .80434 | 4.11088 | .82148 | 4.60174 | 43 |
| 44 | .77052 | 3.35761 | .78754 | 3.70673 | .80462 | 4.11835 | .82177 | 4.61073 | 44 |
| 45 | .77080 | 3.36299 | .78782 | 3.71303 | .80491 | 4.12583 | .82206 | 4.61976 | 45 |
| 46 | .77108 | 3.36839 | .78811 | 3.71935 | .80520 | 4.13334 | .82234 | 4.62881 | 46 |
| 47 | .77137 | 3.37380 | .78839 | 3.72569 | .80548 | 4.14087 | .82263 | 4.63790 | 47 |
| 48 | .77165 | 3.37923 | .78868 | 3.73205 | .80577 | 4.14842 | .82292 | 4.64701 | 48 |
| 49 | .77193 | 3.38466 | .78896 | 3.73843 | .80605 | 4.15599 | .82320 | 4.65616 | 49 |
| 50 | .77222 | 3.39012 | .78924 | 3.74482 | .80634 | 4.16359 | .82349 | 4.66533 | 50 |
| 51 | .77250 | 3.39558 | .78953 | 3.75123 | .80662 | 4.17121 | .82377 | 4.67454 | 51 |
| 52 | .77278 | 3.40106 | .78981 | 3.75766 | .80691 | 4.17886 | .82406 | 4.68377 | 52 |
| 53 | .77307 | 3.40656 | .79010 | 3.76411 | .80719 | 4.18652 | .82435 | 4.69304 | 53 |
| 54 | .77335 | 3.41206 | .79038 | 3.77057 | .80748 | 4.19421 | .82463 | 4.70234 | 54 |
| 55 | .77363 | 3.41759 | .79067 | 3.77705 | .80776 | 4.20193 | .82492 | 4.71166 | 55 |
| 56 | .77392 | 3.42314 | .79095 | 3.78355 | .80805 | 4.20966 | .82521 | 4.72102 | 56 |
| 57 | .77420 | 3.42867 | .79123 | 3.79007 | .80833 | 4.21742 | 82549 | 4.73041 | 57 |
| 58 | .77448 | 3.43424 | .79152 | 3.79661 | .80862 | 4.22521 | .82578 | 4.73983 | 58 |
| 59 | .77477 | 3.43982 | .79180 | 3.80316 | .80891 | 4.23301 | .82607 | 4.74929 | 59 |
| 60 | .77505 | 3.44541 | .79209 | 3.80973 | .80919 | 4.24084 | .82635 | 4.75877 | 60 |

| ′ | 80° | | 81° | | 82° | | 83° | | ′ |
|---|---|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .82635 | 4.75877 | .84357 | 5.39245 | .86083 | 6.18530 | .87813 | 7.20551 | 0 |
| 1 | .82664 | 4.76829 | .84385 | 5.40422 | .86112 | 6.20020 | .87842 | 7.22500 | 1 |
| 2 | .82692 | 4.77784 | .84414 | 5.41602 | .86140 | 6.21517 | .87871 | 7.24457 | 2 |
| 3 | .82721 | 4.78742 | .84443 | 5.42787 | .86169 | 6.23019 | .87900 | 7.26425 | 3 |
| 4 | .82750 | 4.79703 | .84471 | 5.43977 | .86198 | 6.24529 | .87929 | 7.28402 | 4 |
| 5 | .82778 | 4.80667 | .84500 | 5.45171 | .86227 | 6.26044 | .87957 | 7.30388 | 5 |
| 6 | .82807 | 4.81635 | .84529 | 5.46369 | .86256 | 6.27566 | .87986 | 7.32384 | 6 |
| 7 | .82836 | 4.82606 | .84558 | 5.47572 | .86284 | 6.29095 | .88015 | 7.34390 | 7 |
| 8 | .82864 | 4.83581 | .84586 | 5.48779 | .86313 | 6.30630 | .88044 | 7.36405 | 8 |
| 9 | .82893 | 4.84558 | .84615 | 5.49991 | .86342 | 6.32171 | .88073 | 7.38431 | 9 |
| 10 | .82922 | 4.85539 | .84644 | 5.51208 | .86371 | 6.33719 | .88102 | 7.40466 | 10 |
| 11 | .82950 | 4.86524 | .84673 | 5.52429 | .86400 | 6.35274 | .88131 | 7.42511 | 11 |
| 12 | .82979 | 4.87511 | .84701 | 5.53655 | .86428 | 6.36835 | .88160 | 7.44566 | 12 |
| 13 | .83008 | 4.88502 | .84730 | 5.54886 | .86457 | 6.38403 | .88188 | 7.46632 | 13 |
| 14 | .83036 | 4.89497 | .84759 | 5.56121 | .86486 | 6.39978 | .88217 | 7.48707 | 14 |
| 15 | .83065 | 4.90495 | .84788 | 5.57361 | .86515 | 6.41560 | .88246 | 7.50793 | 15 |
| 16 | .83094 | 4.91496 | .84816 | 5.58606 | .86544 | 6.43148 | .88275 | 7.52889 | 16 |
| 17 | .83122 | 4.92501 | .84845 | 5.59855 | .86573 | 6.44743 | .88304 | 7.54996 | 17 |
| 18 | .83151 | 4.93509 | .84874 | 5.61110 | .86601 | 6.46346 | .88333 | 7.57113 | 18 |
| 19 | .83180 | 4.94521 | .84903 | 5.62369 | .86630 | 6.47955 | .88362 | 7.59241 | 19 |
| 20 | .83208 | 4.95536 | .84931 | 5.63633 | .86659 | 6.49571 | .88391 | 7.61379 | 20 |
| 21 | .83237 | 4.96555 | .84960 | 5.64902 | .86688 | 6.51194 | .88420 | 7.63528 | 21 |
| 22 | .83266 | 4.97577 | .84989 | 5.66176 | .86717 | 6.52825 | .88448 | 7.65688 | 22 |
| 23 | .83294 | 4.98603 | .85018 | 5.67454 | .86746 | 6.54462 | .88477 | 7.67859 | 23 |
| 24 | .83323 | 4.99633 | .85046 | 5.68738 | .86774 | 6.56107 | .88506 | 7.70041 | 24 |
| 25 | .83352 | 5.00666 | .85075 | 5.70027 | .86803 | 6.57759 | .88535 | 7.72234 | 25 |
| 26 | .83380 | 5.01703 | .85104 | 5.71321 | .86832 | 6.59418 | .88564 | 7.74438 | 26 |
| 27 | .83409 | 5.02743 | .85133 | 5.72620 | .86861 | 6.61085 | .88593 | 7.76653 | 27 |
| 28 | .83438 | 5.03787 | .85162 | 5.73924 | .86890 | 6.62759 | .88622 | 7.78880 | 28 |
| 29 | .83467 | 5.04834 | .85190 | 5.75233 | .86919 | 6.64441 | .88651 | 7.81118 | 29 |
| 30 | .83495 | 5.05886 | .85219 | 5.76547 | .86947 | 6.66130 | .88680 | 7.83367 | 30 |
| 31 | .83524 | 5.06941 | .85248 | 5.77866 | .86976 | 6.67826 | .88709 | 7.85628 | 31 |
| 32 | .83553 | 5.08000 | .85277 | 5.79191 | .87005 | 6.69530 | .88737 | 7.87901 | 32 |
| 33 | .83581 | 5.09062 | .85305 | 5.80521 | .87034 | 6.71242 | .88766 | 7.90186 | 33 |
| 34 | .83610 | 5.10129 | .85334 | 5.81856 | .87063 | 6.72962 | .88795 | 7.92482 | 34 |
| 35 | .83639 | 5.11199 | .85363 | 5.83196 | .87092 | 6.74689 | .88824 | 7.94791 | 35 |
| 36 | .83667 | 5.12273 | .85392 | 5.84542 | .87120 | 6.76424 | .88853 | 7.97111 | 36 |
| 37 | .83696 | 5.13350 | .85420 | 5.85893 | .87149 | 6.78167 | .88882 | 7.99444 | 37 |
| 38 | .83725 | 5.14432 | .85449 | 5.87250 | .87178 | 6.79918 | .88911 | 8.01788 | 38 |
| 39 | .83754 | 5.15517 | .85478 | 5.88612 | .87207 | 6.81677 | .88940 | 8.04146 | 39 |
| 40 | .83782 | 5.16607 | .85507 | 5.89979 | .87236 | 6.83443 | .88969 | 8.06515 | 40 |
| 41 | .83811 | 5.17700 | .85536 | 5.91352 | .87265 | 6.85218 | .88998 | 8.08897 | 41 |
| 42 | .83840 | 5.18797 | .85564 | 5.92731 | .87294 | 6.87001 | .89027 | 8.11292 | 42 |
| 43 | .83868 | 5.19898 | .85593 | 5.94115 | .87322 | 6.88792 | .89055 | 8.13699 | 43 |
| 44 | .83897 | 5.21004 | .85622 | 5.95505 | .87351 | 6.90592 | .89084 | 8.16120 | 44 |
| 45 | .83926 | 5.22113 | .85651 | 5.96900 | .87380 | 6.92400 | .89113 | 8.18553 | 45 |
| 46 | .83954 | 5.23226 | .85680 | 5.98301 | .87409 | 6.94216 | .89142 | 8.20999 | 46 |
| 47 | .83983 | 5.24343 | .85708 | 5.99708 | .87438 | 6.96040 | .89171 | 8.23459 | 47 |
| 48 | .84012 | 5.25464 | .85737 | 6.01120 | .87467 | 6.97873 | .89200 | 8.25931 | 48 |
| 49 | .84041 | 5.26590 | .85766 | 6.02538 | .87496 | 6.99714 | .89229 | 8.28417 | 49 |
| 50 | .84069 | 5.27719 | .85795 | 6.03962 | .87524 | 7.01565 | .89258 | 8.30917 | 50 |
| 51 | .84098 | 5.28853 | .85823 | 6.05392 | .87553 | 7.03423 | .89287 | 8.33430 | 51 |
| 52 | .84127 | 5.29991 | .85852 | 6.06828 | .87582 | 7.05291 | .89316 | 8.35957 | 52 |
| 53 | .84155 | 5.31133 | .85881 | 6.08269 | .87611 | 7.07167 | .89345 | 8.38497 | 53 |
| 54 | .84184 | 5.32279 | .85910 | 6.09717 | .87640 | 7.09052 | .89374 | 8.41052 | 54 |
| 55 | .84213 | 5.33429 | .85939 | 6.11171 | .87669 | 7.10946 | .89403 | 8.43620 | 55 |
| 56 | .84242 | 5.34584 | .85967 | 6.12630 | .87698 | 7.12849 | .89431 | 8.46203 | 56 |
| 57 | .84270 | 5.35743 | .85996 | 6.14096 | .87726 | 7.14760 | .89460 | 8.48800 | 57 |
| 58 | .84299 | 5.36906 | .86025 | 6.15568 | .87755 | 7.16681 | .89489 | 8.51411 | 58 |
| 59 | .84328 | 5.38073 | .86054 | 6.17046 | .87784 | 7.18612 | .89518 | 8.54037 | 59 |
| 60 | .84357 | 5.39245 | .86083 | 6.18530 | .87813 | 7.20551 | .89547 | 8.56677 | 60 |

| ′ | 84° |  | 85° |  | 86° |  | ′ |
|---|---|---|---|---|---|---|---|
|  | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. |  |
| 0 | .89547 | 8.56677 | .91284 | 10.47371 | .93024 | 13.33559 | 0 |
| 1 | .89576 | 8.59332 | .91313 | 10.51199 | .93053 | 13.39547 | 1 |
| 2 | .89605 | 8.62002 | .91342 | 10.55052 | .93082 | 13.45586 | 2 |
| 3 | .89634 | 8.64687 | .91371 | 10.58932 | .93111 | 13.51676 | 3 |
| 4 | .89663 | 8.67387 | .91400 | 10.62837 | .93140 | 13.57817 | 4 |
| 5 | .89692 | 8.70103 | .91429 | 10.66769 | .93169 | 13.64011 | 5 |
| 6 | .89721 | 8.72833 | .91458 | 10.70728 | .93198 | 13.70258 | 6 |
| 7 | .89750 | 8.75579 | .91487 | 10.74714 | .93227 | 13.76558 | 7 |
| 8 | .89779 | 8.78341 | .91516 | 10.78727 | .93257 | 13.82913 | 8 |
| 9 | .89808 | 8.81119 | .91545 | 10.82768 | .93286 | 13.89323 | 9 |
| 10 | .89836 | 8.83912 | .91574 | 10.86837 | .93315 | 13.95788 | 10 |
| 11 | .89865 | 8.86722 | .91603 | 10.90934 | .93344 | 14.02310 | 11 |
| 12 | .89894 | 8.89547 | .91632 | 10.95060 | .93373 | 14.08890 | 12 |
| 13 | .89923 | 8.92389 | .91661 | 10.99214 | .93402 | 14.15527 | 13 |
| 14 | .89952 | 8.95248 | .91690 | 11.03397 | .93431 | 14.22223 | 14 |
| 15 | .89981 | 8.98123 | .91719 | 11.07610 | .93460 | 14.28979 | 15 |
| 16 | .90010 | 9.01015 | .91748 | 11.11852 | .93489 | 14.35795 | 16 |
| 17 | .90039 | 9.03923 | .91777 | 11.16125 | .93518 | 14.42672 | 17 |
| 18 | .90068 | 9.06849 | .91806 | 11.20427 | .93547 | 14.49611 | 18 |
| 19 | .90097 | 9.09792 | .91835 | 11.24761 | .93576 | 14.56614 | 19 |
| 20 | .90126 | 9.12752 | .91864 | 11.29125 | .93605 | 14.63679 | 20 |
| 21 | .90155 | 9.15730 | .91893 | 11.33521 | .93634 | 14.70810 | 21 |
| 22 | .90184 | 9.18725 | .91922 | 11.37948 | .93663 | 14.78005 | 22 |
| 23 | .90213 | 9.21739 | .91951 | 11.42408 | .93692 | 14.85268 | 23 |
| 24 | .90242 | 9.24770 | .91980 | 11.46900 | .93721 | 14.92597 | 24 |
| 25 | .90271 | 9.27819 | .92009 | 11.51424 | .93750 | 14.99995 | 25 |
| 26 | .90300 | 9.30887 | .92038 | 11.55982 | .93779 | 15.07462 | 26 |
| 27 | .90329 | 9.33973 | .92067 | 11.60572 | .93808 | 15.14909 | 27 |
| 28 | .90358 | 9.37077 | .92096 | 11.65197 | .93837 | 15.22607 | 28 |
| 29 | .90386 | 9.40201 | .92125 | 11.69856 | .93866 | 15.30287 | 29 |
| 30 | .90415 | 9.43343 | .92154 | 11.74550 | .93895 | 15.38041 | 30 |
| 31 | .90444 | 9.46505 | .92183 | 11.79278 | .93924 | 15.45869 | 31 |
| 32 | .90473 | 9.49685 | .92212 | 11.84042 | .93953 | 15.53772 | 32 |
| 33 | .90502 | 9.52886 | .92241 | 11.88841 | .93982 | 15.61751 | 33 |
| 34 | .90531 | 9.56106 | .92270 | 11.93677 | .94011 | 15.69808 | 34 |
| 35 | .90560 | 9.59346 | .92299 | 11.98549 | .94040 | 15.77944 | 35 |
| 36 | .90589 | 9.62605 | .92328 | 12.03458 | .94069 | 15.86150 | 36 |
| 37 | .90618 | 9.65885 | .92357 | 12.08404 | .94098 | 15.94456 | 37 |
| 38 | .90647 | 9.69186 | .92386 | 12.13388 | .94127 | 16.02885 | 38 |
| 39 | .90676 | 9.72507 | .92415 | 12.18411 | .94156 | 16.11297 | 39 |
| 40 | .90705 | 9.75849 | .92444 | 12.23472 | .94186 | 16.19843 | 40 |
| 41 | .90734 | 9.79212 | .92473 | 12.28572 | .94215 | 16.28476 | 41 |
| 42 | .90763 | 9.82596 | .92502 | 12.33712 | .94244 | 16.37196 | 42 |
| 43 | .90792 | 9.86001 | .92531 | 12.38891 | .94273 | 16.46005 | 43 |
| 44 | .90821 | 9.89428 | .92560 | 12.44112 | .94302 | 16.54903 | 44 |
| 45 | .90850 | 9 92877 | .92589 | 12.49373 | .94331 | 16.63893 | 45 |
| 46 | .90879 | 9.96348 | .92618 | 12.54676 | .94360 | 16.72975 | 46 |
| 47 | .90908 | 9.99841 | .92647 | 12.60021 | .94389 | 16.82152 | 47 |
| 48 | .90937 | 10.03356 | .92676 | 12.65408 | .94418 | 16.91424 | 48 |
| 49 | .90966 | 10.06894 | .92705 | 12.70838 | .94447 | 17.00794 | 49 |
| 50 | .90995 | 10.10455 | .92734 | 12.76312 | .94476 | 17.10262 | 50 |
| 51 | .91024 | 10.14039 | .92763 | 12.81829 | .94505 | 17.19830 | 51 |
| 52 | .91053 | 10.17646 | .92792 | 12.87391 | .94534 | 17.29501 | 52 |
| 53 | .91082 | 10.21277 | .92821 | 12.92999 | .94563 | 17.39274 | 53 |
| 54 | .91111 | 10.24932 | .92850 | 12.98651 | .94592 | 17.49153 | 54 |
| 55 | .91140 | 10.28610 | .92879 | 13 04350 | .94621 | 17.59139 | 55 |
| 56 | .91169 | 10.32313 | .92908 | 13.10096 | .94650 | 17.69233 | 56 |
| 57 | .91197 | 10.36040 | .92937 | 13.15889 | .94679 | 17.79438 | 57 |
| 58 | .91226 | 10.39792 | .92966 | 13.21730 | .94708 | 17.89755 | 58 |
| 59 | .91255 | 10.43569 | .92995 | 13.27620 | .94737 | 18.00185 | 59 |
| 60 | .91284 | 10.47371 | .93024 | 13.33559 | .94766 | 18.10732 | 60 |

| ′ | 87° | | 88° | | 89° | | ′ |
|---|---|---|---|---|---|---|---|
| | Vers. | Exsec. | Vers. | Exsec. | Vers. | Exsec. | |
| 0 | .94766 | 18.10732 | .96510 | 27.65371 | .98255 | 56.29869 | 0 |
| 1 | .94795 | 18.21397 | .96539 | 27.89440 | .98284 | 57.26976 | 1 |
| 2 | .94825 | 18.32182 | .96568 | 28.13917 | .98313 | 58.27431 | 2 |
| 3 | .94854 | 18.43088 | .96597 | 28.38812 | .98342 | 59.31411 | 3 |
| 4 | .94883 | 18.54119 | .96626 | 28.64137 | .98371 | 60.39105 | 4 |
| 5 | .94912 | 18.65275 | .96655 | 28.89903 | .98400 | 61.50715 | 5 |
| 6 | .94941 | 18.76560 | .96684 | 29.16120 | .98429 | 62.66460 | 6 |
| 7 | .94970 | 18.87976 | .96714 | 29.42802 | .98458 | 63.86572 | 7 |
| 8 | .94999 | 18.99524 | .96743 | 29.69960 | .98487 | 65.11304 | 8 |
| 9 | .95028 | 19.11208 | .96772 | 29.97607 | .98517 | 66.40927 | 9 |
| 10 | .95057 | 19.23028 | .96801 | 30.25758 | .98546 | 67.75736 | 10 |
| 11 | .95086 | 19.34989 | .96830 | 30.54425 | .98575 | 69.16047 | 11 |
| 12 | .95115 | 19.47093 | .96859 | 30.83623 | .98604 | 70.62207 | 12 |
| 13 | .95144 | 19.59341 | .96888 | 31.13366 | .98633 | 72.14583 | 13 |
| 14 | .95173 | 19.71737 | .96917 | 31.43671 | .98662 | 73.73586 | 14 |
| 15 | .95202 | 19.84283 | .96946 | 31.74554 | .98691 | 75.39655 | 15 |
| 16 | .95231 | 19.96982 | .96975 | 32.06030 | .98720 | 77.13274 | 16 |
| 17 | .95260 | 20.09838 | .97004 | 32.38118 | .98749 | 78.94968 | 17 |
| 18 | .95289 | 20.22852 | .97033 | 32.70835 | .98778 | 80.85315 | 18 |
| 19 | .95318 | 20.36027 | .97062 | 33.04199 | .98807 | 82.84947 | 19 |
| 20 | .95347 | 20.49368 | .97092 | 33.38232 | .98836 | 84.94561 | 20 |
| 21 | .95377 | 20.62876 | .97121 | 33.72952 | .98866 | 87.14924 | 21 |
| 22 | .95406 | 20.76555 | .97150 | 34.08380 | .98895 | 89.46886 | 22 |
| 23 | .95435 | 20.90403 | .97179 | 34.44539 | .98924 | 91.91387 | 23 |
| 24 | .95464 | 21.04440 | .97208 | 34.81452 | .98953 | 94.49471 | 24 |
| 25 | .95493 | 21.18653 | .97237 | 35.19141 | .98982 | 97.22303 | 25 |
| 26 | .95522 | 21.33050 | .97266 | 35.57633 | .99011 | 100.1119 | 26 |
| 27 | .95551 | 21.47635 | .97295 | 35.96953 | .99040 | 103.1757 | 27 |
| 28 | .95580 | 21.62413 | .97324 | 36.37127 | .99069 | 106.4311 | 28 |
| 29 | .95609 | 21.77386 | .97353 | 36.78185 | .99098 | 109.8966 | 29 |
| 30 | .95638 | 21.92559 | .97382 | 37.20155 | .99127 | 113.5930 | 30 |
| 31 | .95667 | 22.07935 | .97411 | 37.63068 | .99156 | 117.5444 | 31 |
| 32 | .95696 | 22.23520 | .97440 | 38.06957 | .99186 | 121.7780 | 32 |
| 33 | .95725 | 22.39316 | .97470 | 38.51855 | .99215 | 126.3253 | 33 |
| 34 | .95754 | 22.55329 | .97499 | 38.97797 | .99244 | 131.2223 | 34 |
| 35 | .95783 | 22.71563 | .97528 | 39.44820 | .99273 | 136.5111 | 35 |
| 36 | .95812 | 22.88022 | .97557 | 39.92963 | .99302 | 142.2406 | 36 |
| 37 | .95842 | 23.04712 | .97586 | 40.42266 | .99331 | 148.4684 | 37 |
| 38 | .95871 | 23.21637 | .97615 | 40.92772 | .99360 | 155.2623 | 38 |
| 39 | .95900 | 23.38802 | .97644 | 41.44525 | .99389 | 162.7083 | 39 |
| 40 | .95929 | 23.56212 | .97673 | 41.97571 | .99418 | 170.8883 | 40 |
| 41 | .95958 | 23.73873 | .97702 | 42.51961 | .99447 | 179.9350 | 41 |
| 42 | .95987 | 23.91790 | .97731 | 43.07746 | .99476 | 189.9868 | 42 |
| 43 | .96016 | 24.09969 | .97760 | 43.64980 | .99505 | 201.2212 | 43 |
| 44 | .96045 | 24.28414 | .97789 | 44.23720 | .99535 | 213.8600 | 44 |
| 45 | .96074 | 24.47134 | .97819 | 44.84026 | .99564 | 228.1839 | 45 |
| 46 | .96103 | 24.66132 | .97848 | 45.45963 | .99593 | 244.5540 | 46 |
| 47 | .96132 | 24.85417 | .97877 | 46.09596 | .99622 | 263.4427 | 47 |
| 48 | .96161 | 25.04994 | .97906 | 46.74997 | .99651 | 285.4795 | 48 |
| 49 | .96190 | 25.24869 | .97935 | 47.42241 | .99680 | 311.5230 | 49 |
| 50 | .96219 | 25.45051 | .97964 | 48.11406 | .99709 | 342.7752 | 50 |
| 51 | .96248 | 25.65546 | .97993 | 48.82576 | .99738 | 380.9723 | 51 |
| 52 | .96277 | 25.86360 | .98022 | 49.55840 | .99767 | 428.7187 | 52 |
| 53 | .96307 | 26.07503 | .98051 | 50.31290 | .99796 | 490.1070 | 53 |
| 54 | .96336 | 26.28981 | .98080 | 51.09027 | .99825 | 571.9581 | 54 |
| 55 | .96365 | 26.50804 | .98109 | 51.89156 | .99855 | 686.5496 | 55 |
| 56 | .96394 | 26.72978 | .98138 | 52.71790 | .99884 | 858.4369 | 56 |
| 57 | .96423 | 26.95513 | .98168 | 53.57046 | .99913 | 1144.916 | 57 |
| 58 | .96452 | 27.18417 | .98197 | 54.45053 | .99942 | 1717.874 | 58 |
| 59 | .96481 | 27.41700 | .98226 | 55.35946 | .99971 | 3436.747 | 59 |
| 60 | .96510 | 27.65371 | .98255 | 56.29869 | 1.00000 | Infinite | 60 |

| $\phi^\circ$ | $y = lC$ | | $x = l(1 - E)$ | | $\phi^\circ$ | $y = lC$ | | $x = l(1 - E)$ | |
|---|---|---|---|---|---|---|---|---|---|
| | $C$ | Dif. | $E$ | Dif. | | $C$ | Dif. | $E$ | Dif. |
| 0° 10′ | 0.00097 | 97 | 0.00000 | 0 | 10° 10′ | 0.05901 | 97 | 0.00314 | 11 |
| 20 | 194 | 97 | 0 | 1 | 20 | 5998 | 96 | 325 | 10 |
| 30 | 291 | 97 | 1 | 0 | 30 | 6094 | 96 | 335 | 11 |
| 40 | 388 | 97 | 1 | 1 | 40 | 6190 | 96 | 346 | 11 |
| 50 | 485 | 97 | 2 | 1 | 50 | 6286 | 97 | 357 | 11 |
| 1 | 0.00582 | 97 | 0.00003 | 1 | 11 | 0.06383 | 96 | 0.00368 | 11 |
| 10 | 679 | 97 | 4 | 1 | 10 | 6479 | 96 | 379 | 12 |
| 20 | 776 | 97 | 5 | 2 | 20 | 6575 | 96 | 391 | 11 |
| 30 | 873 | 97 | 7 | 1 | 30 | 6671 | 96 | 402 | 12 |
| 40 | 970 | 97 | 8 | 2 | 40 | 6767 | 96 | 414 | 12 |
| 50 | 1067 | 97 | 10 | 2 | 50 | 6863 | 96 | 426 | 12 |
| 2 | 0.01164 | 96 | 0.00012 | 2 | 12 | 0.06959 | 96 | 0.00438 | 12 |
| 10 | 1260 | 97 | 14 | 3 | 10 | 7055 | 96 | 450 | 12 |
| 20 | 1357 | 97 | 17 | 2 | 20 | 7151 | 96 | 462 | 13 |
| 30 | 1454 | 97 | 19 | 3 | 30 | 7247 | 96 | 475 | 13 |
| 40 | 1551 | 97 | 22 | 2 | 40 | 7343 | 96 | 488 | 14 |
| 50 | 1648 | 97 | 24 | 3 | 50 | 7439 | 96 | 502 | 12 |
| 3 | 0.01745 | 97 | 0.00027 | 4 | 13 | 0.07535 | 96 | 0.00514 | 13 |
| 10 | 1842 | 97 | 31 | 3 | 10 | 7631 | 96 | 527 | 13 |
| 20 | 1939 | 97 | 34 | 3 | 20 | 7727 | 96 | 540 | 14 |
| 30 | 2036 | 97 | 37 | 4 | 30 | 7823 | 96 | 554 | 13 |
| 40 | 2133 | 96 | 41 | 4 | 40 | 7919 | 96 | 567 | 14 |
| 50 | 2229 | 97 | 45 | 4 | 50 | 8015 | 95 | 581 | 14 |
| 4 | 0.02326 | 97 | 0.00049 | 4 | 14 | 0.08110 | 96 | 0.00595 | 15 |
| 10 | 2423 | 97 | 53 | 4 | 10 | 8206 | 96 | 610 | 14 |
| 20 | 2520 | 97 | 57 | 5 | 20 | 8302 | 95 | 624 | 15 |
| 30 | 2617 | 97 | 62 | 4 | 30 | 8397 | 95 | 639 | 14 |
| 40 | 2714 | 96 | 66 | 5 | 40 | 8493 | 95 | 653 | 15 |
| 50 | 2810 | 97 | 71 | 5 | 50 | 8588 | 96 | 668 | 15 |
| 5 | 0.02907 | 97 | 0.00076 | 5 | 15 | 0.08684 | 96 | 0.00683 | 15 |
| 10 | 3004 | 97 | 81 | 6 | 10 | 8780 | 95 | 698 | 16 |
| 20 | 3101 | 97 | 87 | 5 | 20 | 8875 | 95 | 714 | 15 |
| 30 | 3198 | 96 | 92 | 6 | 30 | 8970 | 96 | 729 | 16 |
| 40 | 3294 | 97 | 98 | 6 | 40 | 9066 | 95 | 745 | 16 |
| 50 | 3391 | 97 | 104 | 6 | 50 | 9161 | 96 | 761 | 16 |
| 6 | 0.03488 | 97 | 0.00110 | 6 | 16 | 0.09257 | 95 | 0.00777 | 16 |
| 10 | 3585 | 96 | 116 | 6 | 10 | 9352 | 95 | 793 | 17 |
| 20 | 3681 | 97 | 122 | 7 | 20 | 9447 | 96 | 810 | 16 |
| 30 | 3778 | 97 | 129 | 6 | 30 | 9543 | 95 | 826 | 17 |
| 40 | 3875 | 96 | 135 | 7 | 40 | 9638 | 95 | 843 | 17 |
| 50 | 3971 | 97 | 142 | 7 | 50 | 9733 | 95 | 860 | 17 |
| 7 | 0.04068 | 97 | 0.00149 | 7 | 17 | 0.09828 | 95 | 0.00877 | 17 |
| 10 | 4165 | 96 | 156 | 8 | 10 | 9923 | 95 | 894 | 17 |
| 20 | 4261 | 97 | 164 | 7 | 20 | 10018 | 95 | 911 | 18 |
| 30 | 4358 | 97 | 171 | 8 | 30 | 10113 | 95 | 929 | 18 |
| 40 | 4455 | 96 | 179 | 8 | 40 | 10208 | 95 | 947 | 17 |
| 50 | 4551 | 97 | 187 | 8 | 50 | 10303 | 95 | 964 | 18 |
| 8 | 0.04648 | 96 | 0.00195 | 8 | 18 | 0.10398 | 95 | 0.00982 | 19 |
| 10 | 4744 | 97 | 203 | 8 | 10 | 10493 | 95 | 1001 | 18 |
| 20 | 4841 | 96 | 211 | 9 | 20 | 10588 | 95 | 1019 | 19 |
| 30 | 4937 | 97 | 220 | 9 | 30 | 10683 | 95 | 1038 | 18 |
| 40 | 5034 | 96 | 229 | 8 | 40 | 10778 | 95 | 1056 | 19 |
| 50 | 5130 | 97 | 237 | 9 | 50 | 10873 | 94 | 1075 | 19 |
| 9 | 0.05227 | 96 | 0.00246 | 10 | 19 | 0.10967 | 95 | 0.01094 | 19 |
| 10 | 5323 | 97 | 256 | 9 | 10 | 11062 | 95 | 1113 | 20 |
| 20 | 5420 | 96 | 265 | 10 | 20 | 11157 | 94 | 1133 | 19 |
| 30 | 5516 | 96 | 275 | 9 | 30 | 11251 | 95 | 1152 | 20 |
| 40 | 5612 | 97 | 284 | 10 | 40 | 11346 | 94 | 1172 | 20 |
| 50 | 5709 | 96 | 294 | 10 | 50 | 11440 | 95 | 1192 | 20 |
| 10 | 5805 | 96 | 304 | 10 | 20 | 11535 | 188 | 1212 | 40 |

| $\phi°$ | $y = lC$ |  | $x = l(1 - E)$ |  | $\phi°$ | $y = lC$ |  | $x = l(1 - E)$ |  |
|---|---|---|---|---|---|---|---|---|---|
|  | $C$ | Dif. | $E$ | Dif. |  | $C$ | Dif. | $E$ | Dif. |
| 20° 20′ | 0.11723 | 189 | 0.01252 | 41 | 30° 30′ | 0.17388 | 273 | 0.02797 | 91 |
| 40 | 11912 | 189 | 1293 | 42 | 31 | 17661 | 273 | 2888 | 93 |
| 21 | 12101 | 188 | 1335 | 42 | 30 | 17934 | 272 | 2981 | 94 |
| 20 | 12289 | 188 | 1377 | 44 | 32 | 18206 | 272 | 3075 | 95 |
| 40 | 12477 | 188 | 1421 | 43 | 30 | 18478 | 271 | 3170 | 97 |
| 22 | 0.12665 | 188 | 0.01464 | 45 | 33 | 0.18749 | 270 | 0.03267 | 98 |
| 20 | 12853 | 187 | 1509 | 45 | 30 | 19019 | 269 | 3365 | 99 |
| 40 | 13040 | 188 | 1554 | 45 | 34 | 19288 | 269 | 3464 | 101 |
| 23 | 13228 | 187 | 1599 | 47 | 30 | 19557 | 269 | 3565 | 102 |
| 20 | 13415 | 187 | 1646 | 47 | 35 | 19826 | 268 | 3667 | 104 |
| 40 | 13602 | 187 | 1693 | 47 | 30 | 20094 | 267 | 3771 | 105 |
| 24 | 0.13789 | 186 | 0.01740 | 49 | 36 | 0.20361 | 266 | 0.03876 | 107 |
| 20 | 13975 | 187 | 1789 | 49 | 30 | 20627 | 266 | 3983 | 107 |
| 40 | 14162 | 186 | 1838 | 49 | 37 | 20893 | 265 | 4090 | 109 |
| 25 | 14348 | 186 | 1887 | 50 | 30 | 21158 | 265 | 4199 | 111 |
| 20 | 14534 | 186 | 1937 | 51 | 38 | 21423 | 263 | 4310 | 112 |
| 40 | 14720 | 185 | 1988 | 52 | 30 | 21686 | 263 | 4422 | 113 |
| 26 | 0.14905 | 186 | 0.02040 | 52 | 39 | 0.21949 | 263 | 0.04535 | 114 |
| 20 | 15091 | 185 | 2092 | 52 | 30 | 22212 | 262 | 4649 | 116 |
| 40 | 15276 | 185 | 2144 | 54 | 40 | 22474 | 521 | 4765 | 236 |
| 27 | 15461 | 184 | 2198 | 54 | 41 | 22995 | 518 | 5001 | 240 |
| 20 | 15645 | 185 | 2252 | 55 | 42 | 23513 | 515 | 5241 | 246 |
| 40 | 15830 | 184 | 2307 | 55 | 43 | 24028 | 512 | 5487 | 252 |
| 28 | 0.16014 | 184 | 0.02362 | 56 | 44 | 24540 | 509 | 5739 | 256 |
| 20 | 16198 | 184 | 2418 | 56 | 45 | 0.25049 | 505 | 0.05995 | 261 |
| 40 | 16382 | 183 | 2474 | 57 | 46 | 25554 | 503 | 6256 | 267 |
| 29 | 16565 | 184 | 2531 | 58 | 47 | 26057 | 499 | 6523 | 271 |
| 20 | 16749 | 183 | 2589 | 59 | 48 | 26556 | 496 | 6794 | 276 |
| 40 | 16932 | 182 | 2648 | 59 | 49 | 27052 | 492 | 7070 | 282 |
| 30 | 17114 | 274 | 2707 | 90 | 50 | 27544 |  | 7352 |  |

## TABLE XV.—DEFLECTION-ANGLES FOR TRANSITION-CURVES.

| Transit at $P.T.C.$, $n'' = 0$.<br>$(\delta_0°) = \frac{I_1°}{3}A_0 - B_0$ |  |  |  |  |  |  |  |  |  | Tr. at quarter-point, $n'' = \frac{1}{4}$<br>$(\delta_{\frac{1}{4}}°) = \frac{I_1°}{3}A_{\frac{1}{4}} - B_{\frac{1}{4}}$ |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $n$ | $\phi$ for $\frac{I_1}{3} = 1$ | $A_0$ | $B_0$ for $\frac{I_1}{3} =$ |  |  |  |  |  |  | $A_{\frac{1}{4}}$ | $B_{\frac{1}{4}}$ for $\frac{I_1}{3} =$ |  |  |  |  | $n$ |
|  |  |  | 4° | 6° | 8° | 10° | 12° | 14° | 16° |  | 4° | 8° | 12° | 14° | 16° |  |
| .0 | .00 | .00 |  |  |  |  |  |  |  | .0625 |  |  |  |  |  | .0 |
| .05 | .0075 | .0025 |  |  |  |  |  |  |  | .0775 |  |  |  |  |  | .05 |
| .1 | .03 | .01 |  |  |  |  |  |  |  | .0975 |  |  |  |  |  | .1 |
| .15 | .0675 | .0225 |  |  |  |  |  |  |  | .1225 |  |  |  |  |  | .15 |
| .2 | .12 | .04 |  |  |  |  |  |  |  | .1525 |  |  |  |  |  | .2 |
| .25 | .1875 | .0625 |  |  |  |  |  |  |  | .1875 |  |  |  |  |  | .25 |
| .3 | .27 | .09 |  |  |  |  |  |  |  | .2275 |  |  |  |  |  | .3 |
| .35 | .3675 | .1225 |  |  |  |  |  |  |  | .2725 |  |  |  |  |  | .35 |
| .4 | .48 | .16 |  |  |  |  |  |  |  | .3225 |  |  |  |  |  | .4 |
| .45 | .6075 | .2025 |  |  |  |  |  | 1 | 1 | .3775 |  |  |  |  |  | .45 |
| .5 | .75 | .25 |  |  |  |  | 1 | 1 | 1 | .4375 |  |  |  |  |  | .5 |
| .55 | .9075 | .3025 |  |  |  | 1 | 1 | 2 | 3 | .5025 |  |  |  |  |  | .55 |
| .6 | 1.08 | .36 |  |  | 1 | 1 | 2 | 3 | 4 | .5725 |  |  |  |  | 1 | .6 |
| .65 | 1.2675 | .4225 |  |  | 1 | 2 | 3 | 5 | 7 | .6475 |  |  | 1 | 1 | 2 | .65 |
| .7 | 1.47 | .49 |  | 1 | 1 | 3 | 5 | 7 | 11 | .7275 |  | 1 | 2 | 3 | 4 | .7 |
| .75 | 1.6875 | .5625 |  | 1 | 2 | 4 | 7 | 11 | 17 | .8125 |  | 1 | 3 | 4 | 6 | .75 |
| .8 | 1.92 | .64 |  | 1 | 3 | 6 | 11 | 17 | 25 | .9025 |  | 1 | 4 | 6 | 9 | .8 |
| .85 | 2.1675 | .7225 | 1 | 2 | 4 | 9 | 15 | 24 | 36 | .9975 |  | 2 | 6 | 10 | 15 | .85 |
| .9 | 2.43 | .81 | 1 | 3 | 6 | 12 | 21 | 34 | 51 | 1.0975 |  | 3 | 9 | 15 | 22 | .9 |
| .95 | 2.7075 | .9025 | 1 | 4 | 9 | 17 | 30 | 47 | 71 | 1.2025 | 1 | 4 | 14 | 22 | 33 | .95 |
| 1. | 3. | 1. | 1 | 5 | 12 | 23 | 41 | 64 | 97 | 1.3125 | 1 | 6 | 20 | 31 | 47 | 1. |

## TABLE XV.—DEFLECTION ANGLES FOR TRANSITION CURVES.

**Transit at mid-point, $n'' = \frac{1}{2}$.**

$$(\delta_{\frac{1}{2}}°) = \frac{I_1°}{3}A_{\frac{1}{2}} - B_{\frac{1}{2}}$$

| $n$ | $\phi$ for $\frac{I_1}{3} = 1$ | $A_{\frac{1}{2}}$ | $B_{\frac{1}{2}}$ for $\frac{I_1°}{3}=$ | | |
|---|---|---|---|---|---|
| | | | 8° | 12° | 16° |
| .0 | .00 | .25 | | 1 | 1 |
| .05 | .0075 | .2775 | | | 1 |
| .1 | .03 | .31 | | | 1 |
| .15 | .0675 | .3475 | | | 1 |
| .2 | .12 | .39 | | | |
| 25 | .1875 | .4375 | | | |
| .3 | .27 | .49 | | | |
| .35 | .3675 | .5475 | | | |
| .4 | .48 | .61 | | | |
| .45 | .6075 | .6775 | | | |
| .5 | .75 | .75 | | | |
| .55 | .9075 | .8275 | | | |
| .6 | 1.08 | .91 | | | |
| .65 | 1.2675 | .9975 | | | |
| .7 | 1.47 | 1.09 | | | |
| .75 | 1.6875 | 1.1875 | | | 1 |
| .8 | 1.92 | 1.29 | | 1 | 1 |
| .85 | 2.1675 | 1.3975 | | 1 | 3 |
| .9 | 2.43 | 1.51 | 1 | 2 | 5 |
| .95 | 2.7075 | 1.6275 | 1 | 3 | 8 |
| 1. | 3. | 1.75 | 2 | 6 | 14 |

**Tr. at three-quarter point, $n''=\frac{3}{4}$.**

$$(\delta_{\frac{3}{4}}°) = \frac{I_1°}{3}A_{\frac{3}{4}} - B_{\frac{3}{4}}$$

| $A_{\frac{3}{4}}$ | $B_{\frac{3}{4}}$ for $\frac{I_1°}{3} =$ | | | | $n$ |
|---|---|---|---|---|---|
| | 6° | 10° | 14° | 16° | |
| .5625 | 1 | 4 | 11 | 17 | .0 |
| .6025 | 1 | 4 | 10 | 15 | .05 |
| .6475 | 1 | 3 | 8 | 12 | .1 |
| .6975 | 1 | 2 | 7 | 10 | .15 |
| .7525 | | 2 | 6 | 8 | .2 |
| .8125 | | 1 | 4 | 6 | .25 |
| .8775 | | 1 | 3 | 4 | .3 |
| .9475 | | 1 | 2 | 3 | .35 |
| 1 0225 | | | 1 | 2 | .4 |
| 1.1025 | | | 1 | 1 | .45 |
| 1.1875 | | | | 1 | .5 |
| 1.2775 | | | | | .55 |
| 1.3725 | | | | | .6 |
| 1.4725 | | | | | .65 |
| 1.5775 | | | | | .7 |
| 1.6875 | | | | | .75 |
| 1.8025 | | | | | .8 |
| 1.9225 | | | | | .85 |
| 2.0475 | | | | | .9 |
| 2.1775 | | | | | .95 |
| 2.3125 | | | 1 | 1 | 1. |

**Transit at $P.C._1$, $n'' = 1$.**

$$(\delta_1°) = \frac{I_1°}{3}A_1 - B_1$$

| $n$ | $\phi$ for $\frac{I_1}{3} = 1$ | $A_1$ | $B_1$ for $\frac{I_1°}{3} =$ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 4° | 6° | 8° | 10° | 12° | 14° | 16° |
| .0 | .00 | 1. | 1 | 5 | 12 | 23 | 41 | 64 | 97 |
| .05 | .0075 | 1.0525 | 1 | 4 | 11 | 20 | 36 | 58 | 86 |
| .1 | .03 | 1.11 | 1 | 4 | 9 | 18 | 32 | 51 | 76 |
| .15 | .0675 | 1.1725 | 1 | 3 | 8 | 16 | 28 | 44 | 66 |
| .2 | .12 | 1.24 | 1 | 3 | 7 | 13 | 23 | 37 | 56 |
| .25 | .1875 | 1.3125 | 1 | 2 | 6 | 11 | 20 | 31 | 47 |
| .3 | .27 | 1.39 | 1 | 2 | 5 | 9 | 16 | 26 | 39 |
| .35 | .3675 | 1.4725 | | 2 | 4 | 7 | 13 | 21 | 31 |
| .4 | .48 | 1.56 | | 1 | 3 | 6 | 10 | 16 | 24 |
| .45 | .6075 | 1.6525 | | 1 | 2 | 4 | 8 | 12 | 18 |
| .5 | .75 | 1.75 | | 1 | 2 | 3 | 6 | 9 | 14 |
| .55 | .9075 | 1.8525 | | | 1 | 2 | 4 | 6 | 9 |
| .6 | 1.08 | 1.96 | | | 1 | 1 | 3 | 4 | 6 |
| .65 | 1.2675 | 2.0725 | | | | 1 | 2 | 3 | 4 |
| .7 | 1.47 | 2.19 | | | | | 1 | 1 | 2 |
| .75 | 1.6875 | 2.3125 | | | | | | 1 | 1 |
| .8 | 1.92 | 2.44 | | | | | | | |
| .85 | 2.1675 | 2.5725 | | | | | | | |
| .9 | 2.43 | 2.71 | | | | | | | |
| .95 | 2.7075 | 2.8525 | | | | | | | |
| 1. | 3. | 3. | | | | | | | |

**Transit at $P.T.C._1$, or $P.C._1$, deflections from tangent to circular curve.**

$$(\delta_O°) = \frac{I_1°}{3}A_O + B_1$$

| $A_O$ | $B_1$ for $\frac{I_1°}{3} =$ | | | | | | | $n$ |
|---|---|---|---|---|---|---|---|---|
| | 4° | 6° | 8° | 10° | 12° | 14° | 16° | |
| 2. | 1 | 5 | 12 | 23 | 41 | 64 | 97 | .0 |
| 1.9475 | 1 | 4 | 11 | 20 | 36 | 58 | 86 | .05 |
| 1.89 | 1 | 4 | 9 | 18 | 32 | 51 | 76 | .1 |
| 1.8275 | 1 | 3 | 8 | 16 | 28 | 44 | 66 | .15 |
| 1.76 | 1 | 3 | 7 | 13 | 23 | 37 | 56 | .2 |
| 1.6875 | 1 | 2 | 6 | 11 | 20 | 31 | 47 | .25 |
| 1.61 | 1 | 2 | 5 | 9 | 16 | 26 | 39 | .3 |
| 1.5275 | | 2 | 4 | 7 | 13 | 21 | 31 | .35 |
| 1.44 | | 1 | 3 | 6 | 10 | 16 | 24 | .4 |
| 1.3475 | | 1 | 2 | 4 | 8 | 12 | 18 | .45 |
| 1.25 | | 1 | 2 | 3 | 6 | 9 | 14 | .5 |
| 1.1475 | | | 1 | 2 | 4 | 6 | 9 | .55 |
| 1.04 | | | 1 | 1 | 3 | 4 | 6 | .6 |
| .9275 | | | | 1 | 2 | 3 | 4 | .65 |
| .81 | | | | | 1 | 1 | 2 | .7 |
| 6875 | | | | | | 1 | 1 | .75 |
| .56 | | | | | | | | .8 |
| .4275 | | | | | | | | .85 |
| .29 | | | | | | | | .9 |
| .1475 | | | | | | | | .95 |
| .00 | | | | | | | | 1. |

| $l_1$ | 2° Curve. | | | | | | | | 3° Curve. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | .40 | 40 | .09 | | | .02 | 20 | .01 | .60 | 40 | .13 | | | .03 | 20 | .02 | 40 |
| 60 | .60 | 60 | .21 | | | 5 | 30 | 3 | .90 | 60 | .31 | | | 8 | 30 | 4 | 60 |
| 80 | .80 | 80 | .37 | | | 9 | 40 | 5 | 1.20 | 80 | .56 | | | .14 | 40 | 7 | 80 |
| 100 | 1.00 | 100 | .58 | | | .14 | 50 | 7 | 1.50 | 100 | .88 | | | .22 | 50 | .11 | 100 |
| 120 | 1.20 | 120 | .84 | | | .21 | 60 | .10 | 1.80 | 120 | 1.26 | | | .32 | 60 | .16 | 120 |
| 140 | 1.40 | 140 | 1.14 | | | .28 | 70 | .14 | 2.10 | 140 | 1.71 | | | .43 | 70 | .21 | 140 |
| 160 | 1.60 | 160 | 1.49 | | | .37 | 80 | .19 | 2.40 | 160 | 2.23 | | | .56 | 80 | .28 | 160 |
| 180 | 1.80 | 180 | 1.89 | | | .47 | 90 | .24 | 2.70 | 180 | 2.82 | | .01 | .71 | 90 | .35 | 180 |
| 200 | 2.00 | 200 | 2.33 | | | .58 | 100 | .29 | 3.00 | 200 | 3.49 | | 1 | .87 | 100 | .44 | 200 |
| 220 | 2.20 | 220 | 2.84 | | | .70 | 110 | .35 | 3.30 | 220 | 4.23 | | 1 | 1.06 | 110 | .53 | 220 |
| 240 | 2.40 | 240 | 3.35 | | | .84 | 120 | .42 | 3.60 | 239.9 | 5.03 | | 1 | 1.26 | 120 | .63 | 240 |
| 260 | 2.60 | 259.9 | 3.93 | | .01 | .98 | 130 | .49 | 3.90 | 259.9 | 5.90 | | 2 | 1.48 | 130 | .74 | 260 |
| 280 | 2.80 | 279.9 | 4.56 | | 1 | 1.14 | 140 | .57 | 4.20 | 279.8 | 6.84 | | 2 | 1.71 | 140 | .86 | 280 |
| 300 | 3.00 | 299.9 | 5.24 | | 1 | 1.31 | 150 | .65 | 4.50 | 299.8 | 7.85 | .01 | 2 | 1.96 | 150 | .98 | 300 |
| 320 | 3.20 | 319.9 | 5.96 | | 2 | 1.49 | 160 | .74 | 4.80 | 319.7 | 8.93 | 1 | 2 | 2.23 | 160 | 1.12 | 320 |
| 340 | 3.40 | 339.9 | 6.73 | | 2 | 1.68 | 170 | .84 | 5.10 | 339.7 | 10.08 | 1 | 3 | 2.52 | 170 | 1.26 | 340 |
| 360 | 3.60 | 359.9 | 7.54 | | 2 | 1.88 | 180 | .94 | 5.40 | 359.7 | 11.30 | 1 | 3 | 2.83 | 179.9 | 1.41 | 360 |
| 380 | 3.80 | 379.8 | 8.40 | .01 | 2 | 2.10 | 190 | 1.05 | 5.70 | 379.6 | 12.59 | 1 | 4 | 3.15 | 189.9 | 1.57 | 380 |
| 400 | 4.00 | 399.8 | 9.30 | 1 | 3 | 2.32 | 200 | 1.16 | 6.00 | 399.6 | 13.95 | 1 | 5 | 3.49 | 199.9 | 1.74 | 400 |
| 420 | 4.20 | 419.8 | 10.25 | 1 | 4 | 2.56 | 210 | 1.28 | 6.30 | 419.5 | 15.38 | 2 | 7 | 3.85 | 209.9 | 1.92 | 420 |
| 440 | 4.40 | 439.7 | 11.26 | 1 | 4 | 2.81 | 219.9 | 1.41 | 6.60 | 439.4 | 16.88 | 2 | 8 | 4.22 | 219.9 | 2.11 | 440 |
| 460 | 4.60 | 459.7 | 12.31 | 1 | 4 | 3.08 | 229.9 | 1.54 | 6.90 | 459.4 | 18.45 | 2 | 9 | 4.61 | 229.9 | 2.31 | 460 |
| 480 | 4.80 | 479.7 | 13.40 | 1 | 5 | 3.35 | 239.9 | 1.68 | 7.20 | 479.3 | 20.08 | 2 | .10 | 5.02 | 239.9 | 2.51 | 480 |
| 500 | 5.00 | 499.6 | 14.54 | 1 | 6 | 3.63 | 249.9 | 1.82 | 7.50 | 499.2 | 21.78 | 3 | .11 | 5.45 | 249.9 | 2.72 | 500 |
| 520 | 5.20 | 519.6 | 15.72 | 1 | 7 | 3.93 | 259.9 | 1.96 | 7.80 | 519.0 | 23.56 | 3 | .12 | 5.89 | 259.8 | 2.94 | 520 |
| 540 | 5.40 | 539.5 | 16.95 | 2 | 7 | 4.24 | 269.9 | 2.12 | 8.10 | 538.9 | 25.41 | 3 | .14 | 6.35 | 269.8 | 3.18 | 540 |
| 560 | 5.60 | 559.5 | 18.23 | 2 | 8 | 4.56 | 279.9 | 2.28 | 8.40 | 558.8 | 27.32 | 4 | .16 | 6.83 | 279.8 | 3.42 | 560 |
| 580 | 5.80 | 579.4 | 19.56 | 2 | 9 | 4.89 | 289.9 | 2.44 | 8.70 | 578.7 | 29.30 | 4 | .18 | 7.33 | 289.8 | 3.66 | 580 |
| 600 | 6.00 | 599.3 | 20.93 | 2 | 9 | 5.23 | 299.9 | 2.61 | 9.00 | 598.5 | 31.36 | 5 | .20 | 7.84 | 299.7 | 3.92 | 600 |
| 620 | 6.20 | 619.3 | 22.35 | 2 | .10 | 5.59 | 309.9 | 2.79 | 9.30 | 618.4 | 33.48 | 6 | .22 | 8.37 | 309.7 | 4.19 | 620 |
| 640 | 6.40 | 639.2 | 23.81 | 2 | .11 | 5.95 | 319.8 | 2.97 | 9.60 | 638.2 | 35.67 | 6 | .24 | 8.92 | 319.7 | 4.46 | 640 |
| 660 | 6.60 | 659.1 | 25.32 | 3 | .12 | 6.33 | 329.8 | 3.16 | 9.90 | 658.0 | 37.93 | 6 | .27 | 9.48 | 329.6 | 4.74 | 660 |
| 680 | 6.80 | 679.0 | 26.87 | 3 | .13 | 6.72 | 339.8 | 3.36 | 10.20 | 677.8 | 40.26 | 7 | .30 | 10.07 | 339.6 | 5.03 | 680 |
| 700 | 7.00 | 699.0 | 28.47 | 4 | .14 | 7.12 | 349.8 | 3.56 | 10.50 | 697.6 | 42.66 | 7 | .33 | 10.67 | 349.5 | 5.33 | 700 |

# TABLE XVI.—TRANSITION CURVE TABLE.

| $l_1$ | 4° Curve. | | | | | | | | 5° Curve. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 0.80 | 40 | .18 | | | .04 | 20 | .02 | 1.00 | 40 | .28 | | −.01 | .06 | 20 | .03 | 40 |
| 60 | 1.20 | 60 | .42 | | | .10 | 30 | 5 | 1.50 | 60 | .52 | | 1 | .13 | 30 | 6 | 60 |
| 80 | 1.60 | 80 | .74 | | | .18 | 40 | 9 | 2.00 | 80 | .93 | | 1 | .23 | 40 | .12 | 80 |
| 100 | 2.00 | 100 | 1.16 | | | .29 | 50 | .14 | 2.50 | 100 | 1.45 | | 1 | .36 | 50 | .18 | 100 |
| 120 | 2.40 | 120 | 1.67 | | | .42 | 60 | .21 | 3.00 | 120 | 2.09 | | 1 | .52 | 60 | .26 | 120 |
| 140 | 2.80 | 140 | 2.28 | | | .57 | 70 | .28 | 3.50 | 140 | 2.85 | | 1 | .71 | 70 | .36 | 140 |
| 160 | 3.20 | 160 | 2.98 | | | .75 | 80 | .37 | 4.00 | 159.9 | 3.72 | | −.01 | .93 | 80 | .47 | 160 |
| 180 | 3.60 | 179.9 | 3.77 | | .01 | .94 | 90 | .47 | 4.50 | 179.9 | 4.71 | | | 1.18 | 90 | .59 | 180 |
| 200 | 4.00 | 199.9 | 4.65 | | 1 | 1.16 | 100 | .58 | 5.00 | 199.8 | 5.81 | | | 1.45 | 100 | .73 | 200 |
| 220 | 4.40 | 219.9 | 5.62 | | 1 | 1.41 | 110 | .70 | 5.50 | 219.8 | 7.03 | .01 | | 1.76 | 110 | .88 | 220 |
| 240 | 4.80 | 239.8 | 6.69 | .01 | 2 | 1.67 | 120 | .84 | 6 00 | 239.7 | 8.37 | 1 | +.01 | 2.09 | 119.9 | 1.05 | 240 |
| 260 | 5.20 | 259.8 | 7.85 | 1 | 2 | 1.96 | 130 | .98 | 6.50 | 259.7 | 9.82 | 1 | 1 | 2.46 | 129.9 | 1.23 | 260 |
| 280 | 5.60 | 279.7 | 9.11 | 1 | 3 | 2.28 | 139.9 | 1.14 | 7.00 | 279.6 | 11.39 | 1 | 2 | 2.85 | 139.9 | 1.42 | 280 |
| 300 | 6.00 | 299.7 | 10.46 | 1 | 3 | 2.62 | 140.9 | 1.31 | 7.50 | 299.5 | 13.07 | 2 | 3 | 3.27 | 149.9 | 1.63 | 300 |
| 320 | 6.40 | 319.6 | 11.90 | 1 | 4 | 2.98 | 159.9 | 1.49 | 8.00 | 319.4 | 14.87 | 2 | 5 | 3.72 | 159.9 | 1.86 | 320 |
| 340 | 6.80 | 339.5 | 13.43 | 1 | 5 | 3.36 | 169.9 | 1.68 | 8.50 | 339.3 | 16.78 | 2 | 6 | 4.20 | 169.9 | 2.10 | 340 |
| 360 | 7.20 | 359.4 | 15.06 | 2 | 6 | 3.77 | 179.9 | 1.88 | 9.00 | 359.1 | 18.81 | 3 | 8 | 4.70 | 179.8 | 2.35 | 360 |
| 380 | 7.60 | 379.3 | 16.78 | 2 | 7 | 4.20 | 189.9 | 2.10 | 9.50 | 379.0 | 20.96 | 3 | .10 | 5.24 | 189.8 | 2.62 | 380 |
| 400 | 8.00 | 399.2 | 18.59 | 2 | 9 | 4.65 | 199.9 | 2.32 | 10.00 | 398.8 | 23.22 | 3 | .12 | 5.81 | 199.8 | 2.90 | 400 |
| 420 | 8.40 | 419.1 | 20.49 | 3 | .11 | 5.12 | 209.8 | 2.56 | 10.50 | 418.6 | 25.59 | 4 | .2 | 6.40 | 209.7 | 3.20 | 420 |
| 440 | 8.80 | 439.0 | 22.49 | 3 | .14 | 5.62 | 219.8 | 2.81 | 11.00 | 438.4 | 28.08 | 5 | .2 | 7.03 | 219.7 | 3.51 | 440 |
| 460 | 9.20 | 458.9 | 24.58 | 3 | .15 | 6.15 | 229.8 | 3.07 | 11.50 | 458.1 | 30.69 | 6 | .2 | 7.68 | 229.7 | 3.83 | 460 |
| 480 | 9.60 | 478.7 | 26.75 | 4 | .17 | 6.69 | 239.8 | 3.34 | 12.00 | 477.9 | 33.40 | 7 | .3 | 8.36 | 239.6 | 4.17 | 480 |
| 500 | 10.00 | 498.5 | 29.02 | 5 | .20 | 7.26 | 249.7 | 3.63 | 12.50 | 497.7 | 36.28 | 7 | .3 | 9.07 | 249.6 | 4.53 | 500 |
| 520 | 10.40 | 518.3 | 31.38 | 6 | .23 | 7.85 | 259.7 | 3.92 | 13.00 | 517.3 | 39.18 | 8 | .4 | 9.81 | 259.5 | 4.90 | 520 |
| 540 | 10.80 | 538.1 | 33.84 | 6 | .25 | 8.47 | 269.6 | 4.23 | 13.50 | 537.0 | 42.24 | 9 | .4 | 10.58 | 269.5 | 5.28 | 540 |
| 560 | 11.20 | 557.9 | 36.39 | 7 | .26 | 9.11 | 279.6 | 4.55 | 14.00 | 556.7 | 45.41 | .1 | .4 | 11.37 | 279.4 | 5.67 | 560 |
| 580 | 11.60 | 577.6 | 39.08 | 7 | .29 | 9.77 | 289.6 | 4.88 | 14.50 | 576.3 | 48.70 | .1 | .5 | 12.20 | 289.3 | 6.08 | 580 |
| 600 | 12.00 | 597.4 | 41.75 | 8 | .32 | 10.45 | 299.5 | 5.22 | 15.00 | 595.9 | 52.10 | .1 | .5 | 13.05 | 299.3 | 6.51 | 600 |
| 620 | 12.40 | 617.1 | 44.57 | 9 | .36 | 11.15 | 309.5 | 5.57 | 15.50 | 615.4 | 55.61 | .1 | .6 | 13.93 | 309.2 | 6.95 | 620 |
| 640 | 12.80 | 636.8 | 47.48 | .1 | .4 | 11.88 | 319.4 | 5.93 | 16.00 | 635.0 | 59.24 | .2 | .6 | 14.85 | 319.1 | 7.39 | 640 |
| 660 | 13.20 | 656.5 | 50.48 | .1 | .5 | 12.64 | 329.4 | 6.30 | 16.50 | 654.5 | 62.98 | .2 | .7 | 15.79 | 329.0 | 7.86 | 660 |
| 680 | 13.60 | 676.2 | 53.58 | .1 | .5 | 13.42 | 339.3 | 6.69 | 17.00 | 674.0 | 66.83 | .2 | .7 | 16.76 | 339.0 | 8.34 | 680 |
| 700 | 14 00 | 695.8 | 56.77 | .1 | .6 | 14.22 | 349.2 | 7.08 | 17.50 | 693.5 | 70.79 | .2 | .8 | 17.75 | 348.9 | 8.84 | 700 |

| $l_1$ | 6° CURVE. | | | | | | | | 7° CURVE. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I^\circ$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I^\circ$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 1.20 | 40 | .28 | | −.01 | .07 | 20 | .03 | 1.40 | 40 | .32 | | −.01 | .08 | 20 | .04 | 40 |
| 60 | 1.80 | 60 | .63 | | 1 | .16 | 30 | .08 | 2.10 | 60 | .73 | | 2 | .18 | 30 | .09 | 60 |
| 80 | 2.40 | 80 | 1.11 | | 1 | .28 | 40 | .14 | 2.80 | 80 | 1.30 | | 2 | .33 | 40 | .16 | 80 |
| 100 | 3.00 | 100 | 1.74 | | 1 | .44 | 50 | .22 | 3.50 | 100 | 2.04 | | 2 | .51 | 50 | .25 | 100 |
| 120 | 3.60 | 120 | 2.51 | | 1 | .63 | 60 | .31 | 4.20 | 119.9 | 2.93 | | 2 | .73 | 60 | .36 | 120 |
| 140 | 4.20 | 139.9 | 3.42 | | 1 | .86 | 70 | .43 | 4.90 | 139.9 | 3.99 | | 2 | 1.00 | 70 | .50 | 140 |
| 160 | 4.80 | 159.9 | 4.47 | | 1 | 1.12 | 80 | .56 | 5.60 | 159.8 | 5.21 | | 2 | 1.30 | 80 | .65 | 160 |
| 180 | 5.40 | 179.8 | 5.66 | | 1 | 1.42 | 90 | .71 | 6.30 | 179.8 | 6.59 | .01 | 2 | 1.65 | 90 | .82 | 180 |
| 200 | 6.00 | 199.8 | 6.98 | .01 | −.01 | 1.75 | 100 | .87 | 7.00 | 199.7 | 8.14 | 1 | −.01 | 2.04 | 99.9 | 1.02 | 200 |
| 220 | 6.60 | 219.7 | 8.44 | 1 | | 2.11 | 109.9 | 1.05 | 7.70 | 219.6 | 9.85 | 1 | | 2.46 | 109.9 | 1.23 | 220 |
| 240 | 7.20 | 239.6 | 10.04 | 1 | +.01 | 2.51 | 119.9 | 1.25 | 8.40 | 239.5 | 11.72 | 2 | | 2.93 | 119.9 | 1.46 | 240 |
| 260 | 7.80 | 259.5 | 11.78 | 1 | 2 | 2.95 | 129.9 | 1.47 | 9.10 | 259.4 | 13.75 | 2 | +.01 | 3.44 | 129.9 | 1.72 | 260 |
| 280 | 8.40 | 279.4 | 13.66 | 2 | 3 | 3.42 | 139.9 | 1.71 | 9.80 | 279.2 | 15.93 | 3 | 1 | 3.99 | 139.9 | 1.99 | 280 |
| 300 | 9.00 | 299.3 | 15.68 | 2 | 4 | 3.92 | 149.9 | 1.96 | 10.50 | 299.0 | 18.28 | 3 | 4 | 4.57 | 149.8 | 2.28 | 300 |
| 320 | 9.60 | 319.1 | 17.83 | 3 | 6 | 4.46 | 159.8 | 2.23 | 11.20 | 318.8 | 20.79 | 4 | 8 | 5.20 | 159.8 | 2.60 | 320 |
| 340 | 10.20 | 338.9 | 20.12 | 3 | 8 | 5.03 | 169.8 | 2.52 | 11.90 | 338.5 | 23.46 | 5 | .11 | 5.87 | 169.7 | 2.93 | 340 |
| 260 | 10.80 | 358.7 | 22.56 | 4 | .11 | 5.64 | 179.8 | 2.82 | 12.60 | 358.3 | 26.29 | 5 | .14 | 6.58 | 179.7 | 3.28 | 360 |
| 380 | 11.40 | 378.5 | 25.13 | 5 | .14 | 6.28 | 189.7 | 3.14 | 13.30 | 378.0 | 29.28 | 6 | .17 | 7.33 | 189.7 | 3.66 | 380 |
| 400 | 12.00 | 398.2 | 27.83 | 5 | .18 | 6.96 | 199.7 | 3.48 | 14.00 | 397.6 | 32.43 | 7 | .22 | 8.12 | 199.6 | 4.05 | 400 |
| 420 | 12.60 | 418.0 | 30.68 | 6 | .2 | 7.68 | 209.7 | 3.83 | 14.70 | 417.2 | 35.74 | 9 | .3 | 8.95 | 209.5 | 4.46 | 420 |
| 440 | 13.20 | 437.7 | 33.66 | 7 | .2 | 8.43 | 219.6 | 4.20 | 15.40 | 436.8 | 39.21 | .10 | .4 | 9.82 | 219.4 | 4.89 | 440 |
| 460 | 13.80 | 457.3 | 36.78 | 8 | .3 | 9.21 | 229.5 | 4.59 | 16.10 | 456.4 | 42.84 | .11 | .4 | 10.73 | 229.4 | 5.35 | 460 |
| 480 | 14.40 | 477.0 | 40.03 | 9 | .3 | 10.03 | 239.5 | 5.00 | 16.80 | 475.9 | 46.62 | .13 | .4 | 11.68 | 239.3 | 5.82 | 480 |
| 500 | 15.00 | 496.7 | 43.42 | .10 | .4 | 10.88 | 249.4 | 5.42 | 17.50 | 495.4 | 50.56 | .14 | .5 | 12.67 | 249.2 | 6.31 | 500 |
| 520 | 15.60 | 516.2 | 46.94 | .1 | .5 | 11.76 | 259.3 | 5.86 | 18.20 | 514.8 | 54.66 | .2 | .5 | 13.70 | 259.1 | 6.82 | 520 |
| 540 | 16.20 | 535.7 | 50.60 | .1 | .5 | 12.68 | 269.2 | 6.32 | 18.90 | 534.2 | 58.91 | .2 | .6 | 14.78 | 269.0 | 7.35 | 540 |
| 560 | 16.80 | 555.2 | 54.39 | .2 | .5 | 13.63 | 279.2 | 6.79 | 19.60 | 553.5 | 63.32 | .2 | .7 | 15.89 | 278.9 | 7.90 | 560 |
| 580 | 17.40 | 574.7 | 58.32 | .2 | .6 | 14.62 | 289.1 | 7.28 | 20.30 | 572.8 | 67.88 | .2 | .8 | 17.04 | 288.8 | 8.47 | 580 |
| 600 | 18.00 | 594.1 | 62.38 | .2 | .8 | 15.64 | 299.0 | 7.79 | 21.00 | 592.0 | 72.60 | .3 | .9 | 18.23 | 298.6 | 9.06 | 600 |
| 620 | 18.60 | 613.5 | 66.58 | .2 | .9 | 16.70 | 308.9 | 8.31 | 21.70 | 611.2 | 77.47 | .3 | 1.0 | 19.46 | 308.5 | 9.67 | 620 |
| 640 | 19.20 | 632.8 | 70.91 | .2 | 1.0 | 17.79 | 318.7 | 8.85 | 22.40 | 630.3 | 82.49 | .3 | 1.1 | 20.73 | 318.4 | 10.29 | 640 |
| 660 | 19.80 | 652.1 | 75.37 | .2 | 1.0 | 18.91 | 328.6 | 9.40 | 23.10 | 649.4 | 87.67 | .3 | 1.2 | 22.04 | 328.3 | 10.94 | 660 |
| 680 | 20.40 | 671.4 | 79.97 | .3 | 1.1 | 20.07 | 338.5 | 9.97 | 23.80 | 668.4 | 93.00 | .4 | 1.3 | 23.39 | 338.1 | 11.60 | 680 |
| 700 | 21.00 | 690.6 | 84.70 | .3 | 1.1 | 21.27 | 348.4 | 10.56 | 24.50 | 687.3 | 98.48 | .4 | 1.5 | 24.78 | 347.9 | 12.28 | 700 |

| $l_1$ | 8° Curve. | | | | | | | | 9° Curve. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I^\circ$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I^\circ$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 1.60 | 40 | .37 | | | .09 | 20 | .05 | 1.80 | 40 | .42 | | | .11 | 20 | .05 | 40 |
| 60 | 2.40 | 60 | .84 | | | .21 | 30 | .11 | 2.70 | 60 | .94 | | | .24 | 30 | .12 | 60 |
| 80 | 3.20 | 80 | 1.49 | | | .37 | 40 | .19 | 3.60 | 80 | 1.67 | | | .42 | 40 | .21 | 80 |
| 100 | 4.00 | 100 | 2.33 | | | .58 | 50 | .29 | 4.50 | 99.9 | 2.62 | | | .66 | 50 | .33 | 100 |
| 120 | 4.80 | 119.9 | 3.35 | | | .84 | 60 | .42 | 5.40 | 119.9 | 3.77 | | .01 | .94 | 60 | .47 | 120 |
| 140 | 5.60 | 139.9 | 4.56 | | .01 | 1.14 | 70 | .57 | 6.30 | 139.8 | 5.13 | .01 | 1 | 1.28 | 70 | .64 | 140 |
| 160 | 6.40 | 159.8 | 5.95 | .01 | 2 | 1.49 | 80 | .74 | 7.20 | 159.7 | 6.70 | 1 | 2 | 1.68 | 80 | .84 | 160 |
| 180 | 7.20 | 179.7 | 7.58 | 1 | 3 | 1.88 | 89.9 | .94 | 8.10 | 179.6 | 8.47 | 1 | 3 | 2.12 | 89.9 | 1.06 | 180 |
| 200 | 8.00 | 199.6 | 9.29 | 1 | 4 | 2.32 | 99.9 | 1.16 | 9.00 | 199.5 | 10.45 | 2 | 4 | 2.61 | 99.9 | 1.30 | 200 |
| 220 | 8.80 | 219.5 | 11.24 | 2 | 6 | 2.81 | 109.9 | 1.40 | 9.90 | 219.3 | 12.64 | 2 | 6 | 3.16 | 109.9 | 1.58 | 220 |
| 240 | 9.60 | 239.3 | 13.38 | 2 | 7 | 3.35 | 119.9 | 1.67 | 10.80 | 239.2 | 15.04 | 3 | 9 | 3.76 | 119.9 | 1.88 | 240 |
| 260 | 10.40 | 259.1 | 15.70 | 3 | .10 | 3.93 | 129.8 | 1.96 | 11.70 | 258.9 | 17.64 | 3 | .12 | 4.42 | 129.8 | 2.20 | 260 |
| 280 | 11.20 | 278.9 | 18.20 | 3 | .13 | 4.56 | 139.8 | 2.27 | 12.60 | 278.7 | 20.45 | 4 | .16 | 5.12 | 139.8 | 2.55 | 280 |
| 300 | 12.00 | 298.7 | 20.88 | 4 | .16 | 5.23 | 149.8 | 2.61 | 13.50 | 298.3 | 23.47 | 5 | .20 | 5.88 | 140.7 | 2.93 | 300 |
| 320 | 12.80 | 318.4 | 23.74 | 5 | .20 | 5.95 | 159.7 | 2.97 | 14.40 | 318.0 | 26.69 | 6 | .24 | 6.69 | 159.7 | 3.33 | 320 |
| 340 | 13.60 | 338.1 | 26.79 | 6 | .24 | 6.71 | 169.7 | 3.35 | 15.30 | 337.6 | 30.11 | 8 | .30 | 7.55 | 169.6 | 3.76 | 340 |
| 360 | 14.40 | 357.7 | 30.02 | 7 | .29 | 7.52 | 179.6 | 3.75 | 16.20 | 357.1 | 33.73 | 9 | .36 | 8.45 | 179.5 | 4.21 | 360 |
| 380 | 15.20 | 377.3 | 33.43 | 8 | .34 | 8.37 | 189.5 | 4.17 | 17.10 | 376.6 | 37.56 | .11 | .43 | 9.41 | 189.4 | 4.69 | 380 |
| 400 | 16.00 | 396.9 | 37.02 | .10 | .41 | 9.27 | 199.5 | 4.62 | 18.00 | 396.1 | 41.59 | .12 | .51 | 10.43 | 199.3 | 5.19 | 400 |
| 420 | 16.80 | 416.4 | 40.79 | .1 | .5 | 10.22 | 209.4 | 5.09 | 18.90 | 415.4 | 45.82 | .1 | .6 | 11.49 | 209.2 | 5.72 | 420 |
| 440 | 17.60 | 435.9 | 44.74 | .1 | .6 | 11.21 | 219.3 | 5.58 | 19.80 | 434.7 | 50.25 | .2 | .6 | 12.61 | 210.1 | 6.27 | 440 |
| 460 | 18.40 | 455.3 | 48.87 | .1 | .7 | 12.25 | 229.2 | 6.10 | 20.70 | 454.0 | 54.88 | .2 | .7 | 13.78 | 229.0 | 6.84 | 460 |
| 480 | 19.20 | 474.6 | 53.18 | 2 | .7 | 13.34 | 239.1 | 6.64 | 21.60 | 473.2 | 59.70 | .2 | .9 | 14.99 | 238.8 | 7.44 | 480 |
| 500 | 20.00 | 493.9 | 57.66 | .2 | .8 | 14.47 | 249.0 | 7.19 | 22.50 | 492.3 | 64.72 | .2 | 1.0 | 16.26 | 248.7 | 8.07 | 500 |
| 520 | 20.80 | 513.2 | 62.82 | .2 | .9 | 15.64 | 258.8 | 7.77 | 23.40 | 511.4 | 69.94 | .3 | 1.1 | 17.58 | 258.5 | 8.72 | 520 |
| 540 | 21.60 | 532.4 | 67.16 | .2 | 1.0 | 16.86 | 268.7 | 8.37 | 24.30 | 530.4 | 75.35 | .3 | 1.3 | 18.95 | 268.3 | 9.39 | 540 |
| 560 | 22.40 | 551.5 | 72.18 | .3 | 1.0 | 18.13 | 278.6 | 9.00 | 25.20 | 549.2 | 80.96 | .3 | 1.5 | 20.37 | 278.1 | 10.08 | 560 |
| 580 | 23.20 | 570.6 | 77.37 | .3 | 1.2 | 19.45 | 288.4 | 9.65 | 26.10 | 568.0 | 86.76 | .4 | 1.6 | 21.84 | 287.9 | 10.80 | 580 |
| 600 | 24.00 | 589.6 | 82.73 | .3 | 1.4 | 20.81 | 298.2 | 10.31 | 27.00 | 586.7 | 92.75 | .4 | 1.8 | 23.36 | 297.7 | 11.55 | 600 |
| 620 | 24.80 | 608.5 | 88.26 | .4 | 1.4 | 22.21 | 308.1 | 11.00 | 27.90 | 605.3 | 98.93 | .5 | 2.0 | 24.98 | 307.4 | 12.31 | 620 |
| 640 | 25.60 | 627.3 | 93.96 | .4 | 1.6 | 23.66 | 317.9 | 11.71 | 28.80 | 624.0 | 105.30 | .5 | 2.2 | 26.55 | 317.2 | 13.10 | 640 |
| 660 | 26.40 | 646.1 | 99.84 | .4 | 1.9 | 25.15 | 327.6 | 12.44 | 29.70 | 642.5 | 111.86 | .6 | 2.3 | 28.23 | 327.0 | 13.92 | 660 |
| 680 | 27.20 | 664.8 | 105.88 | .5 | 2.0 | 26.68 | 337.4 | 13.19 | 30.60 | 660.9 | 118.60 | .6 | 2.5 | 29.94 | 336.8 | 14.76 | 680 |
| 700 | 28.00 | 683.5 | 112.09 | .5 | 2.2 | 28.25 | 347.2 | 13.96 | 31.50 | 679.1 | 125.53 | .7 | 2.7 | 31.71 | 346.5 | 15.62 | 700 |

| $l_1$ | 10° CURVE. | | | | | | | | 11° CURVE. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 2.00 | 40 | .47 | | | .12 | 20 | .06 | 2.20 | 40 | .51 | | | .18 | 20 | .06 | 40 |
| 60 | 3.00 | 60 | 1.05 | | | .26 | 30 | .13 | 3.30 | 60 | 1.15 | | | .29 | 30 | .14 | 60 |
| 80 | 4.00 | 80 | 1.86 | | | .47 | 40 | .23 | 4.40 | 80 | 2.05 | | | .51 | 40 | .26 | 80 |
| 100 | 5.00 | 99.9 | 2.91 | | | .73 | 50 | .36 | 5.50 | 99.9 | 3.20 | | | .80 | 50 | .40 | 100 |
| 120 | 6.00 | 119.9 | 4.19 | | .01 | 1.05 | 60 | .52 | 6.60 | 119.8 | 4.60 | .01 | | 1.15 | 60 | .57 | 120 |
| 140 | 7.00 | 139.8 | 5.70 | .01 | 1 | 1.43 | 70 | .71 | 7.70 | 139.7 | 6.25 | 1 | .01 | 1.56 | 70 | .78 | 140 |
| 160 | 8.00 | 159.7 | 7.44 | 1 | 2 | 1.86 | 79.9 | 93 | 8.80 | 159.6 | 8.16 | 1 | 3 | 2.04 | 79.9 | 1.02 | 160 |
| 180 | 9.00 | 179.6 | 9.41 | 1 | 4 | 2.36 | 89.9 | 1.18 | 9.90 | 179.5 | 10.33 | 1 | 5 | 2.58 | 89.9 | 1.29 | 180 |
| 200 | 10.00 | 199.4 | 11.61 | 2 | 6 | 2.91 | 99.9 | 1.45 | 11.00 | 199.3 | 12.75 | 2 | 7 | 3.19 | 99.9 | 1.59 | 200 |
| 220 | 11.00 | 219.2 | 14.04 | 3 | 8 | 3.51 | 109.9 | 1.75 | 12.10 | 219.0 | 15.43 | 3 | .10 | 3.86 | 109.8 | 1.98 | 220 |
| 240 | 12.00 | 239.0 | 16.70 | 3 | .11 | 4.18 | 119.8 | 2.09 | 13.20 | 238.7 | 18.36 | 4 | .13 | 4.60 | 119.8 | 2.30 | 240 |
| 260 | 13.00 | 258.7 | 19.59 | 4 | .15 | 4.90 | 129.8 | 2.45 | 14.30 | 258.4 | 21.54 | 5 | .18 | 5.40 | 129.7 | 2.69 | 260 |
| 280 | 14.00 | 278.3 | 22.71 | 5 | .19 | 5.68 | 139.7 | 2.84 | 15.40 | 278.0 | 24.96 | 6 | .23 | 6.25 | 139.7 | 3.12 | 280 |
| 300 | 15.00 | 297.9 | 26.05 | 6 | .24 | 6.52 | 149.7 | 3.26 | 16.50 | 297.5 | 28.63 | 8 | .28 | 7.17 | 149.6 | 3.58 | 300 |
| 320 | 16.00 | 317.5 | 29.62 | 8 | .29 | 7.42 | 159.6 | 3.70 | 17.60 | 317.0 | 32.55 | .10 | .35 | 8.15 | 159.5 | 4.07 | 320 |
| 340 | 17.00 | 337.0 | 33.41 | 9 | .37 | 8.37 | 169.5 | 4.17 | 18.70 | 336.4 | 36.71 | .11 | .44 | 9.20 | 169.4 | 4.59 | 340 |
| 360 | 18.00 | 356.5 | 37.43 | .11 | .44 | 9.38 | 179.4 | 4.67 | 19.80 | 355.7 | 41.11 | .13 | .52 | 10.31 | 179.3 | 5.13 | 360 |
| 380 | 19.00 | 375.9 | 41.67 | .13 | .52 | 10.45 | 189.3 | 5.20 | 20.90 | 375.0 | 45.76 | .15 | .62 | 11.48 | 189.2 | 5.70 | 380 |
| 400 | 20.00 | 395.2 | 46.13 | .15 | .61 | 11.57 | 199.2 | 5.76 | 22.00 | 394.2 | 50.65 | .18 | .73 | 12.72 | 199.0 | 6.31 | 400 |
| 420 | 21.00 | 414.5 | 50.81 | .2 | .7 | 12.75 | 209.1 | 6.34 | 23.10 | 413.3 | 55.78 | .2 | .8 | 14.01 | 208.9 | 6.95 | 420 |
| 440 | 22.00 | 433.6 | 55.72 | .2 | .8 | 13.99 | 218.9 | 6.95 | 24.20 | 432.2 | 61.15 | .2 | 1.0 | 15.37 | 218.7 | 7.62 | 440 |
| 460 | 23.00 | 452.6 | 60.84 | .2 | .9 | 15.29 | 228.7 | 7.59 | 25.30 | 451.1 | 66.76 | .3 | 1.1 | 16.79 | 228.5 | 8.33 | 460 |
| 480 | 24.00 | 471.7 | 66.18 | .3 | 1.1 | 16.64 | 238.6 | 8.25 | 26.40 | 469.9 | 72.61 | .3 | 1.3 | 18.28 | 238.3 | 9.06 | 480 |
| 500 | 25.00 | 490.6 | 71.73 | .3 | 1.2 | 18.05 | 248.4 | 8.94 | 27.50 | 488.6 | 78.69 | .4 | 1.4 | 19.83 | 248.1 | 9.81 | 500 |
| 520 | 26.00 | 509.4 | 77.50 | .3 | 1.3 | 19.51 | 258 2 | 9.66 | 28.60 | 507.2 | 85.00 | .4 | 1.6 | 21.44 | 257.9 | 10.59 | 520 |
| 540 | 27.00 | 528.1 | 83.48 | .4 | 1.5 | 21.03 | 268.0 | 10.40 | 29.70 | 525.7 | 91.53 | .4 | 1.8 | 23.11 | 267.6 | 11.40 | 540 |
| 560 | 28.00 | 546.8 | 89.67 | .4 | 1.7 | 22.60 | 277.8 | 11.17 | 30.80 | 544.1 | 98.29 | .5 | 2.0 | 24.83 | 277.4 | 12.24 | 560 |
| 580 | 29.00 | 565.3 | 96.07 | .5 | 2.0 | 24.23 | 287.5 | 11.97 | 31.90 | 562.4 | 105.27 | .6 | 2.3 | 26.60 | 287.1 | 13.11 | 580 |
| 600 | 30.00 | 583.8 | 102.68 | .5 | 2.2 | 25.91 | 297.3 | 12.79 | 33.00 | [illegible] | 112.48 | .6 | 2.5 | 28.44 | 296.8 | 14.01 | 600 |
| 620 | 31.00 | 602.1 | 109.49 | .6 | 2.4 | 27.64 | 307.0 | 13.64 | 34.10 | 598.5 | 119.91 | .7 | 2.7 | 30.34 | 306.5 | 14.98 | 620 |
| 640 | 32.00 | 620.3 | 116.51 | .6 | 2.6 | 29.44 | 316.7 | 14.51 | 35.20 | 616.4 | 127.56 | .7 | 3.0 | 32.31 | 316.1 | 15.87 | 640 |
| 660 | 33.00 | 638.4 | 123.73 | .7 | 2.9 | 31.29 | 326.4 | 15.40 | 36.30 | 634.1 | 135.43 | .8 | 3.3 | 34.34 | 325.7 | 16.84 | 660 |
| 680 | 34.00 | 656.5 | 131.15 | .7 | 3.2 | 33.19 | 336.0 | 16.31 | 37.40 | 651.7 | 143.51 | .9 | 3.7 | 36.42 | 335.8 | 17.84 | 680 |
| 700 | 35.00 | 674.3 | 138.77 | .8 | 3.4 | 35.14 | 346.7 | 17.25 | 38 50 | 669.2 | 151.79 | .9 | 4.0 | 38.56 | 344.9 | 18.87 | 700 |

| $l_1$ | 12° CURVE. | | | | | | | | 13° CURVE. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P^{\circ}$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $P^{\circ}$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 2.40 | 40 | .56 | | | .14 | 20 | .07 | 2.60 | 40 | .60 | | | .15 | 20 | .07 | 40 |
| 60 | 3.60 | 60 | 1.26 | | | .32 | 30 | .16 | 3.90 | 60 | 1.36 | | | .34 | 30 | .17 | 60 |
| 80 | 4.80 | 79.9 | 2.23 | | | .56 | 40 | .28 | 5.20 | 79.9 | 2.42 | | | .61 | 40 | .30 | 80 |
| 100 | 6.00 | 99.9 | 3.49 | | | .87 | 50 | .44 | 6.50 | 99.9 | 3.78 | | | .95 | 50 | .47 | 100 |
| 120 | 7.20 | 119.8 | 5.02 | .01 | | 1.26 | 60 | .63 | 7.80 | 119.8 | 5.44 | .01 | | 1.36 | 60 | .68 | 120 |
| 140 | 8.40 | 139.7 | 6.83 | 1 | .01 | 1.71 | 69.9 | .85 | 9.10 | 139.6 | 7.40 | 1 | .02 | 1.85 | 69.9 | .92 | 140 |
| 160 | 9.60 | 159.6 | 8.92 | 1 | 3 | 2.23 | 79.9 | 1.11 | 10.40 | 159.5 | 9.66 | 2 | 4 | 2.42 | 79.9 | 1.21 | 160 |
| 180 | 10.80 | 179.4 | 11.28 | 2 | 5 | 2.82 | 89.9 | 1.41 | 11.70 | 179.3 | 12.22 | 2 | 6 | 3.06 | 89.8 | 1.53 | 180 |
| 200 | 12.00 | 199.1 | 13.92 | 3 | 8 | 3.49 | 99.8 | 1.74 | 13.00 | 199.0 | 15.07 | 3 | .10 | 3.77 | 99.8 | 1.88 | 200 |
| 220 | 13.20 | 218.8 | 16.83 | 4 | .11 | 4.22 | 109.8 | 2.10 | 14.30 | 218.6 | 18.22 | 4 | .13 | 4.56 | 109.8 | 2.28 | 220 |
| 240 | 14.40 | 238.5 | 20.01 | 5 | .15 | 5.01 | 119.7 | 2.50 | 15.60 | 238.2 | 21.66 | 6 | .18 | 5.42 | 119.7 | 2.71 | 240 |
| 260 | 15.60 | 258.1 | 23.47 | 6 | .20 | 5.88 | 129.7 | 2.93 | 16.90 | 257.7 | 25.39 | 7 | .24 | 6.36 | 129.6 | 3.17 | 260 |
| 280 | 16.80 | 277.6 | 27.20 | 8 | .27 | 6.82 | 139.6 | 3.40 | 18.20 | 277.2 | 29.43 | 9 | .31 | 7.38 | 139.5 | 3.68 | 280 |
| 300 | 18.00 | 297.0 | 31.20 | 9 | .34 | 7.82 | 149.5 | 3.90 | 19.50 | 296.5 | 33.76 | .11 | .39 | 8.48 | 149.4 | 4.22 | 300 |
| 320 | 19.20 | 316.4 | 35.46 | .11 | .42 | 8.89 | 159.4 | 4.43 | 20.80 | 315.8 | 38.37 | .13 | .49 | 9.64 | 159.3 | 4.79 | 320 |
| 340 | 20.40 | 335.7 | 39.98 | .13 | .52 | 10.03 | 169.3 | 4.99 | 22.10 | 335.0 | 43.26 | .16 | .60 | 10.87 | 169.2 | 5.40 | 340 |
| 360 | 21.60 | 354.9 | 44.77 | .15 | .62 | 11.24 | 179.1 | 5.59 | 23.40 | 354.1 | 48.43 | .19 | .72 | 12.18 | 179.0 | 6.04 | 360 |
| 380 | 22.80 | 374.0 | 49.83 | .18 | .75 | 12.52 | 189.0 | 6.22 | 24.70 | 373.0 | 53.88 | .22 | .86 | 13.56 | 188.8 | 6.72 | 380 |
| 400 | 24.00 | 393.0 | 55.15 | .21 | .88 | 13.86 | 198.8 | 6.87 | 26.00 | 391.8 | 59.61 | .25 | 1.03 | 15.01 | 198.6 | 7.43 | 400 |
| 420 | 25.20 | 411.9 | 60.73 | .2 | 1.0 | 15.27 | 208.6 | 7.57 | 27.30 | 410.5 | 65.62 | .3 | 1.2 | 16.53 | 208.4 | 8.18 | 420 |
| 440 | 26.40 | 430.8 | 66.56 | .3 | 1.2 | 16.75 | 218.4 | 8.29 | 28.60 | 429.2 | 71.91 | .3 | 1.4 | 18.13 | 218.2 | 8.96 | 440 |
| 460 | 27.60 | 449.4 | 72.64 | .3 | 1.4 | 18.30 | 228.2 | 9.05 | 29.90 | 447.6 | 78.47 | .4 | 1.6 | 19.80 | 227.9 | 9.77 | 460 |
| 480 | 28.80 | 468.0 | 78.98 | .4 | 1.6 | 19.92 | 238.0 | 9.84 | 31.20 | 466.0 | 85.29 | .4 | 1.8 | 21.54 | 237.6 | 10.62 | 480 |
| 500 | 30.00 | 486.4 | 85.57 | .4 | 1.8 | 21.60 | 247.7 | 10.65 | 32.50 | 484.2 | 92.38 | .5 | 2.1 | 23.35 | 247.3 | 11.50 | 500 |
| 520 | 31.20 | 504.8 | 92.40 | .5 | 2.0 | 23.34 | 257.4 | 11.49 | 33.80 | 502.2 | 99.73 | .5 | 2.3 | 25.23 | 257.0 | 12.41 | 520 |
| 540 | 32.40 | 523.0 | 99.48 | .5 | 2.2 | 25.15 | 267.1 | 12.37 | 35.10 | 520.1 | 107.34 | .6 | 2.6 | 27.18 | 266.7 | 13.35 | 540 |
| 560 | 33.60 | 541.0 | 106.80 | .6 | 2.5 | 27.02 | 276.8 | 13.28 | 36.40 | 537.8 | 115.21 | .7 | 2.9 | 29.21 | 276.3 | 14.32 | 560 |
| 580 | 34.80 | 559.0 | 114.36 | .6 | 2.8 | 28.96 | 286.4 | 14.21 | 37.70 | 555.4 | 123.33 | .7 | 3.2 | 31.31 | 285.9 | 15.32 | 580 |
| 600 | 36.00 | 576.8 | 122.16 | .7 | 3.1 | 30.96 | 296.1 | 15.17 | 39.00 | 572.8 | 131.70 | .8 | 3.6 | 33.47 | 295.4 | 16.35 | 600 |
| 620 | 37.20 | 594.4 | 130.19 | .8 | 3.4 | 33.03 | 305.7 | 16.16 | 40.30 | 590.0 | 140.81 | .9 | 4.0 | 35.70 | 304.9 | 17.41 | 620 |
| 640 | 38.40 | 611.9 | 138.45 | .8 | 3.8 | 35.16 | 315.2 | 17.18 | 41.60 | 607.1 | 149.16 | 1.0 | 4.4 | 38.00 | 314.4 | 18.50 | 640 |
| 660 | 39.60 | 629.2 | 146.93 | .9 | 4.1 | 37.35 | 324.8 | 18.23 | 42.90 | 624.0 | 158.23 | 1.1 | 4.8 | 40.36 | 323.9 | 19.62 | 660 |
| 680 | 40.80 | 646.8 | 155.64 | 1.0 | 4.5 | 39.60 | 334.3 | 19.30 | 44.20 | 640.6 | 167.56 | 1.2 | 5.3 | 42.79 | 333.3 | 20.77 | 680 |
| 700 | 42.00 | 663.3 | 164.56 | 1.1 | 5.0 | 41.98 | 343.8 | 20.40 | 45.50 | 657.1 | 177.11 | 1.3 | 5.8 | 45.28 | 342.8 | 21.95 | 700 |

| $l_1$ | 14° CURVE. | | | | | | | | 16° CURVE. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 2.8 | 40 | .65 | | | .16 | 20 | .08 | 3.2 | 40 | .74 | | | .19 | 20 | .09 | 40 |
| 60 | 4.2 | 60 | 1.47 | | | .37 | 30 | .18 | 4.8 | 60 | 1.67 | | | .42 | 30 | .21 | 60 |
| 80 | 5.6 | 79.9 | 2.60 | | | .65 | 40 | .32 | 6.4 | 79.9 | 2.98 | | | .75 | 40 | .37 | 80. |
| 100 | 7.0 | 99.8 | 4.07 | | | 1.02 | 50 | .51 | 8.0 | 99.8 | 4.65 | .01 | .02 | 1.16 | 50 | .58 | 100 |
| 120 | 8.4 | 119.7 | 5.86 | .01 | | 1.47 | 60 | .73 | 9.6 | 119.7 | 6.69 | 1 | 4 | 1.67 | 59.9 | .83 | 120 |
| 140 | 9.8 | 139.6 | 7.97 | 1 | .02 | 1.99 | 69 9 | .99 | 11.2 | 139.5 | 9.10 | 2 | 7 | 2.27 | 69.9 | 1.13 | 140 |
| 160 | 11.2 | 159.4 | 10.40 | 2 | 4 | 2.60 | 79.9 | 1.30 | 12.8 | 159.2 | 11.87 | 2 | .10 | 2.97 | 79.9 | 1.48 | 160 |
| 180 | 12.6 | 179.1 | 13.15 | 3 | 6 | 3.29 | 89.8 | 1.64 | 14.4 | 178.9 | 15.01 | 4 | .14 | 3.76 | 89.8 | 1.87 | 180 |
| 200 | 14.0 | 198.8 | 16.22 | 4 | .10 | 4.06 | 99.8 | 2.03 | 16.0 | 198.5 | 18.51 | 5 | .20 | 4.64 | 99.7 | 2.31 | 200 |
| 220 | 15.4 | 218.4 | 19.61 | 5 | .15 | 4.92 | 109.7 | 2.45 | 17.6 | 217.9 | 22 37 | 6 | .27 | 5.61 | 109.7 | 2.79 | 220 |
| 240 | 16.8 | 237.9 | 23.31 | 6 | .22 | 5.85 | 119.7 | 2.91 | 19.2 | 237.3 | 26.59 | 8 | .35 | 6.68 | 119.5 | 3.32 | 240 |
| 260 | 18.2 | 257.4 | 27.33 | 8 | .29 | 6.86 | 129.5 | 3.41 | 20.8 | 256.6 | 31.16 | .10 | .42 | 7.83 | 129.4 | 3.89 | 260 |
| 280 | 19.6 | 276.7 | 31.66 | .11 | .36 | 7.95 | 139.4 | 3.95 | 22.4 | 275.8 | 36.09 | .13 | .50 | 9.07 | 139.3 | 4.50 | 280 |
| 300 | 21.0 | 296.0 | 36.30 | .13 | .46 | 9.12 | 149.3 | 4.53 | 24.0 | 294.8 | 41.37 | .16 | .63 | 10.40 | 149.1 | 5.15 | 300 |
| 320 | 22.4 | 315.1 | 41.24 | .2 | .6 | 10.36 | 159.2 | 5.14 | 25.6 | 313.7 | 46.99 | .2 | .8 | 11.82 | 158.9 | 5.85 | 320 |
| 340 | 23.8 | 334.2 | 46.49 | .2 | .7 | 11.68 | 169.0 | 5.79 | 27.2 | 332.4 | 52.95 | .2 | 1.0 | 13.33 | 168.7 | 6.59 | 340 |
| 360 | 25.2 | 353.1 | 52 04 | .2 | .8 | 13.09 | 178.8 | 6.48 | 28.8 | 351.0 | 59.24 | .3 | 1.2 | 14.93 | 178.5 | 7.38 | 360 |
| 380 | 26.6 | 371.9 | 57.89 | .2 | 1.0 | 14.58 | 188.6 | 7.21 | 30.4 | 369.4 | 65.86 | .3 | 1.4 | 16.62 | 188.2 | 8.20 | 380 |
| 400 | 28.0 | 390.6 | 64.05 | .3 | 1.2 | 16.14 | 198.4 | 7.98 | 32.0 | 387.7 | 72.82 | .4 | 1.7 | 18.40 | 197.9 | 9.06 | 400 |
| 420 | 29.4 | 409.1 | 70.50 | .3 | 1.4 | 17.78 | 208.2 | 8.78 | 33.6 | 405.8 | 80.10 | .4 | 1.8 | 20.26 | 207.6 | 9.96 | 420 |
| 440 | 30.8 | 427.5 | 77.23 | .4 | 1.6 | 19.50 | 217.9 | 9.62 | 35.2 | 423.7 | 87.70 | .5 | 2.2 | 22.21 | 217.3 | 10.90 | 440 |
| 460 | 32.2 | 445.7 | 84.24 | .4 | 1.8 | 21.29 | 227.6 | 10.49 | 36.8 | 441.4 | 95.61 | .6 | 2.5 | 24.25 | 226.9 | 11.88 | 460 |
| 480 | 33.6 | 463.8 | 91.54 | .5 | 2.1 | 23.16 | 237.3 | 11.39 | 38.4 | 458.9 | 103.84 | .6 | 2.9 | 26.37 | 236.4 | 12.90 | 480 |
| 500 | 35.0 | 481.7 | 99.12 | .6 | 2.4 | 25.11 | 246.9 | 12.32 | 40.0 | 476.2 | 112.37 | .7 | 3.3 | 28.58 | 246.0 | 13.95 | 500 |
| 520 | 36.4 | 499.4 | 106.98 | .6 | 2.7 | 27.13 | 256.5 | 13.29 | 41.6 | 493.3 | 121.19 | .8 | 3.7 | 30.87 | 255.5 | 15.04 | 520 |
| 540 | 37.8 | 517.0 | 115.11 | .7 | 3.0 | 29.22 | 266.1 | 14.29 | 43.2 | 510.1 | 130.30 | .9 | 4.1 | 33.24 | 265.0 | 16.16 | 540 |
| 560 | 39.2 | 534.4 | 123.50 | .8 | 3.4 | 31.39 | 275.7 | 15.33 | 44.8 | 526.7 | 139.70 | 1.0 | 4.6 | 35.69 | 274.4 | 17.32 | 560 |
| 580 | 40.6 | 551.6 | 132.15 | .8 | 3.8 | 33.63 | 285.2 | 16.40 | 46.4 | 543.1 | 149.38 | 1.1 | 5.1 | 38.23 | 283.8 | 18.51 | 580 |
| 600 | 42.0 | 568.6 | 141.07 | .9 | 4.2 | 35.94 | 294.7 | 17.50 | 48.0 | 559.2 | 159.33 | 1.2 | 5.6 | 40.84 | 293.1 | 19.72 | 600 |
| 620 | 43.4 | 585.4 | 150.24 | 1.0 | 4.6 | 38.33 | 304.2 | 18.63 | 49.6 | 575.1 | 169.55 | 1.3 | 6.2 | 43.53 | 302.4 | 20.96 | 620 |
| 640 | 44.8 | 602.0 | 159.66 | 1.1 | 5.1 | 40.79 | 313.6 | 19.79 | 51.2 | 590.8 | 180.03 | 1.4 | 6.8 | 46.30 | 311.7 | 22.24 | 640 |
| 660 | 46.2 | 618 4 | 169.32 | 1.3 | 5.5 | 43.32 | 323.0 | 20.97 | 52.8 | 606.1 | 190.76 | 1.6 | 7.4 | 49.15 | 320.9 | 23.55 | 660 |
| 680 | 47.6 | 634.6 | 179.22 | 1.4 | 6.1 | 45.92 | 332.3 | 22.18 | 54.4 | 621.2 | 201.73 | 1.7 | 8.2 | 52.08 | 330.0 | 24.89 | 680 |
| 700 | 49.0 | 650.5 | 189.35 | 1.5 | 6.7 | 48.58 | 341.6 | 23.42 | 56.0 | 636.0 | 212.95 | 1.8 | 9.0 | 55.09 | 339.1 | 26.25 | 700 |

| $l_1$ | 18° Curve. | | | | | | | | 20° Curve. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 3.6 | 40 | .84 | | | .21 | 20 | .10 | 4.0 | 40 | .93 | | | .23 | 20 | .12 | 40 |
| 60 | 5.4 | 59.9 | 1.88 | | | .47 | 30 | .24 | 6.0 | 59.9 | 2.09 | | | .52 | 30 | .26 | 60 |
| 80 | 7.2 | 79.9 | 3.35 | | | .84 | 40 | .42 | 8.0 | 79.8 | 3.72 | | .01 | .93 | 40 | 0.46 | 80 |
| 100 | 9.0 | 99.8 | 5.23 | .01 | .02 | 1.31 | 50 | .65 | 10.0 | 99.7 | 5.81 | .01 | 2 | 1.45 | 49.9 | 0.72 | 100 |
| 120 | 10.8 | 119.6 | 7.52 | 1 | 5 | 1.88 | 59.9 | .94 | 12.0 | 119.5 | 8.35 | 2 | 6 | 2.09 | 59.9 | 1.04 | 120 |
| 140 | 12.6 | 139.3 | 10.22 | 2 | 8 | 2.56 | 69.9 | 1.28 | 14.0 | 139.2 | 11.35 | 3 | .10 | 2.84 | 69.8 | 1.42 | 140 |
| 160 | 14.4 | 159.0 | 13.34 | 3 | .13 | 3.34 | 79.8 | 1.67 | 16.0 | 158.8 | 14 81 | 4 | .15 | 3.71 | 79.8 | 1.85 | 160 |
| 180 | 16.2 | 178.6 | 16.87 | 4 | .19 | 4.23 | 89.8 | 2.11 | 18.0 | 178.2 | 18.72 | 6 | .22 | 4.70 | 89,7 | 2.34 | 180 |
| 200 | 18.0 | 198.0 | 20.80 | 6 | .25 | 5.22 | 99.7 | 2.60 | 20.0 | 197.6 | 23.07 | 8 | .30 | 5.79 | 99.6 | 2.88 | 200 |
| 220 | 19 8 | 217.4 | 25.13 | 8 | .33 | 6.31 | 109.6 | 3.14 | 22.0 | 216.8 | 27.86 | .10 | .41 | 7.00 | 109.5 | 3.48 | 220 |
| 240 | 21.6 | 236.6 | 29.85 | .10 | .44 | 7.50 | 119.4 | 3.73 | 24.0 | 235.8 | 33.09 | .13 | .54 | 8.31 | 119.3 | 4.13 | 240 |
| 260 | 23.4 | 255.7 | 34.97 | .13 | .57 | 8.79 | 129.3 | 4.37 | 26.0 | 254.7 | 38.75 | .16 | .70 | 9.75 | 129.1 | 4.83 | 260 |
| 280 | 25.2 | 274.6 | 40.48 | .17 | .71 | 10.18 | 139.1 | 5.05 | 28.0 | 273.4 | 44.84 | .20 | .88 | 11.30 | 138.9 | 5.58 | 280 |
| 300 | 27.0 | 293.4 | 46.37 | .20 | .87 | 11.67 | 148.9 | 5.78 | 30.0 | 291.9 | 51.35 | .25 | 1.07 | 12.96 | 148.6 | 6.39 | 300 |
| 320 | 28.8 | 312.0 | 52.65 | .2 | 1.1 | 13.27 | 158.7 | 6.56 | 32.0 | 310.2 | 58.27 | .3 | 1.3 | 14.73 | 158.3 | 7.25 | 320 |
| 340 | 30.6 | 330.4 | 59.30 | .3 | 1.3 | 14.97 | 168.4 | 7.38 | 34.0 | 328.2 | 65.58 | .4 | 1.6 | 16.60 | 168.0 | 8.16 | 340 |
| 360 | 32.4 | 348.7 | 66.32 | .3 | 1.5 | 16.76 | 178.1 | 8.25 | 36.0 | 346.0 | 73.30 | .4 | 1.9 | 18.58 | 177.6 | 9.11 | 360 |
| 380 | 34.2 | 366.7 | 73.70 | .4 | 1.8 | 18.65 | 187.8 | 9.16 | 38.0 | 363.6 | 81.40 | .5 | 2.2 | 20.67 | 187.2 | 10.11 | 380 |
| 400 | 36.0 | 384.5 | 81.43 | .5 | 2.1 | 20.63 | 197.4 | 10.12 | 40.0 | 380.9 | 89.89 | .6 | 2.6 | 22.86 | 196.8 | 11.15 | 400 |
| 420 | 37.8 | 402.1 | 89.51 | .5 | 2.4 | 22.71 | 207.0 | 11.12 | 42.0 | 398.0 | 98.75 | .7 | 3.0 | 25.16 | 206.3 | 12.24 | 420 |
| 440 | 39.6 | 419.5 | 97.94 | .6 | 2.8 | 24.89 | 216.5 | 12.16 | 44.0 | 414.8 | 107.97 | .7 | 3.5 | 27.56 | 215.7 | 13.38 | 440 |
| 460 | 41.4 | 436.6 | 106.72 | .7 | 3.2 | 27.17 | 226.1 | 13.24 | 46.0 | 431.2 | 117.54 | .8 | 3.9 | 30.06 | 225.1 | 14.56 | 460 |
| 480 | 43.2 | 453.4 | 115.83 | .8 | 3.6 | 29.54 | 235.5 | 14.36 | 48.0 | 447.4 | 127.46 | 1.0 | 4.5 | 32.67 | 234.5 | 15.77 | 480 |
| 500 | 45.0 | 470.0 | 125.24 | .9 | 4.1 | 32.00 | 245.0 | 15.52 | 50.0 | 463.2 | 137.71 | 1.1 | 5.1 | 35.37 | 243.8 | 17.02 | 500 |
| 520 | 46.8 | 486.4 | 134.97 | 1.0 | 4.6 | 34.55 | 254.3 | 16.71 | 52.0 | 478.8 | 148.29 | 1.2 | 5.7 | 38.17 | 253.0 | 18.31 | 520 |
| 540 | 48.6 | 502.4 | 145.01 | 1.1 | 5.2 | 37.19 | 263.7 | 17.94 | 54.0 | 494.0 | 159.17 | 1.3 | 6.4 | 41.07 | 262.2 | 19.63 | 540 |
| 560 | 50.4 | 518.2 | 155.34 | 1.2 | 5.8 | 39.92 | 272.9 | 19.20 | 56.0 | 508.8 | 170.36 | 1.5 | 7.2 | 44.07 | 271.3 | 20.99 | 560 |
| 580 | 52.2 | 533.7 | 165.96 | 1.3 | 6.4 | 42.74 | 282.2 | 20.50 | 58.0 | 523.3 | 181.88 | 1.6 | 8 0 | 47.16 | 280.4 | 22.39 | 580 |
| 600 | 54.0 | 548.9 | 176.86 | 1.5 | 7.1 | 45.64 | 291.4 | 21.83 | 60.0 | 537.5 | 193.58 | 1.7 | 8.8 | 50.33 | 289.4 | 23.81 | 600 |
| 620 | 55.8 | 563.8 | 188.03 | 1.6 | 7.8 | 48.63 | 300.5 | 23.20 | 62.0 | 551.2 | 205.60 | 1.8 | 9.8 | 53.60 | 298.3 | 25.26 | 620 |
| 640 | 57.6 | 578.4 | 199.46 | 1.7 | 8.6 | 51.70 | 309.6 | 24.59 | 64.0 | 564.6 | 217.87 | 2.1 | 10.7 | 56.96 | 307.1 | 26.74 | 640 |
| 660 | 59.4 | 592.6 | 211.15 | 1.9 | 9.4 | 54.85 | 318.6 | 26.00 | 66.0 | 577.6 | 230.38 | 2.3 | 11.7 | 60.41 | 315.9 | 28.25 | 660 |
| 680 | 61.2 | 606.5 | 223.09 | 2.1 | 10.3 | 58.09 | 327.6 | 27.45 | 68.0 | 590.3 | 243.12 | 2.4 | 12.8 | 63.94 | 324.6 | 29.77 | 680 |
| 700 | 63.0 | 620.1 | 235.28 | 2.2 | 11.2 | 61.40 | 336.5 | 28.93 | 70.0 | 602.5 | 256.07 | 2.6 | 14.0 | 67.56 | 333.3 | 31.32 | 700 |

| $l_1$ | 22° CURVE. | | | | | | | | 24° CURVE. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 4.4 | 40 | 1.02 | | | .26 | 20 | .13 | 4.8 | 40 | 1.12 | | | .28 | 20 | .14 | 40 |
| 60 | 6.6 | 59.9 | 2.30 | | | .58 | 30 | .29 | 7.2 | 59.9 | 2.51 | | | .63 | 30 | .31 | 60 |
| 80 | 8.8 | 79.8 | 4.09 | | .01 | 1.02 | 40 | 51 | 9.6 | 79.8 | 4.46 | .01 | .02 | 1.12 | 40 | 56 | 80 |
| 100 | 11.0 | 99.6 | 6.38 | .01 | 2 | 1.60 | 49.9 | 80 | 12.0 | 99.6 | 6.96 | 1 | 4 | 1.74 | 49.9 | .87 | 100 |
| 120 | 13.2 | 119.4 | 9.18 | 2 | 7 | 2.30 | 59.9 | 1.15 | 14.4 | 119.2 | 10.01 | 2 | 8 | 2.51 | 59.9 | 1.25 | 120 |
| 140 | 15.4 | 139.0 | 12.48 | 3 | .12 | 3.13 | 69.8 | 1.56 | 16.8 | 138.8 | 13.60 | 4 | 14 | 3.41 | 69.8 | 1.70 | 140 |
| 160 | 17.6 | 158.5 | 16.27 | 4 | .18 | 4.08 | 79.7 | 2.03 | 19.2 | 158.2 | 17.73 | 5 | .21 | 4.45 | 79.7 | 2.21 | 160 |
| 180 | 19.8 | 177.9 | 20.56 | 6 | .27 | 5.16 | 89.6 | 2.57 | 21.6 | 177.5 | 22.39 | 8 | .31 | 5.62 | 89.6 | 2.79 | 180 |
| 200 | 22.0 | 197.1 | 25.33 | 9 | .37 | 6.37 | 99.5 | 3.16 | 24.0 | 196.5 | 27.57 | .11 | .42 | 6.93 | 99.4 | 3.44 | 200 |
| 220 | 24.2 | 216.1 | 30.58 | .12 | .50 | 7.69 | 109.3 | 3.81 | 26.4 | 215.4 | 33.27 | .15 | .58 | 8.38 | 109.2 | 4.15 | 220 |
| 240 | 26.4 | 235.0 | 36.30 | .15 | .65 | 9.13 | 119.1 | 4.53 | 28.8 | 234.0 | 39.49 | .18 | .77 | 9.97 | 119.0 | 4.92 | 240 |
| 260 | 28.6 | 253.6 | 42.49 | .19 | .83 | 10.71 | 128.9 | 5.30 | 31.2 | 252.4 | 46.20 | .23 | .99 | 11.67 | 128.7 | 5.75 | 260 |
| 280 | 30.8 | 272.0 | 49.14 | .24 | 1.05 | 12.42 | 138.6 | 6.12 | 33.6 | 270.5 | 53.40 | .29 | 1.25 | 13.51 | 138.4 | 6.64 | 280 |
| 300 | 33.0 | 290.2 | 56.24 | .29 | 1.30 | 14.22 | 148.3 | 7.00 | 36.0 | 288.4 | 61.08 | .35 | 1.54 | 15.48 | 148.0 | 7.59 | 300 |
| 320 | 35.2 | 308.1 | 63.78 | .4 | 1.6 | 16.15 | 158.0 | 7.93 | 38.4 | 305.9 | 69.22 | .4 | 1.9 | 17.58 | 157.6 | 8.59 | 320 |
| 340 | 37.4 | 325.8 | 71.75 | .4 | 1.9 | 18.21 | 167.6 | 8.92 | 40.8 | 323.2 | 77.82 | .5 | 2.3 | 19.81 | 167.2 | 9.65 | 340 |
| 360 | 39.6 | 343.2 | 80.15 | .5 | 2.3 | 20.38 | 177.2 | 9.95 | 43.2 | 340.1 | 86.86 | .6 | 2.7 | 22.15 | 176.6 | 10.77 | 360 |
| 380 | 41.8 | 360.3 | 88.95 | .6 | 2.7 | 22.66 | 186.7 | 11.03 | 45.6 | 356.6 | 96.33 | .7 | 3.2 | 24.63 | 186.0 | 11.93 | 380 |
| 400 | 44.0 | 377.0 | 98.15 | .7 | 3.1 | 25.05 | 196.1 | 12.17 | 48.0 | 372.8 | 106.22 | .8 | 3.7 | 27.22 | 195.4 | 13.14 | 400 |
| 420 | 46.2 | 393.5 | 107.75 | .8 | 3.6 | 27.56 | 205.5 | 13.34 | 50.4 | 388.6 | 116.50 | .9 | 4.3 | 29.94 | 204.7 | 14.40 | 420 |
| 440 | 48.4 | 409.6 | 117.72 | .9 | 4.2 | 30.18 | 214.9 | 14.56 | 52.8 | 404.1 | 127.17 | 1.0 | 4.9 | 32.77 | 213.9 | 15.70 | 440 |
| 460 | 50.6 | 425.4 | 128.05 | 1.0 | 4.8 | 32.92 | 224.1 | 15.82 | 55.2 | 419.1 | 138.21 | 1.2 | 5.6 | 35.72 | 223.1 | 17.05 | 460 |
| 480 | 52.8 | 440.8 | 138.73 | 1.1 | 5.5 | 35.75 | 233.3 | 17.12 | 57.6 | 433.7 | 149.60 | 1.3 | 6.4 | 38.77 | 232.1 | 18.44 | 480 |
| 500 | 55.0 | 455.9 | 149.75 | 1.2 | 6.2 | 38.69 | 242.5 | 18.46 | 60.0 | 447.9 | 161.32 | 1.5 | 7.3 | 41.93 | 241.1 | 19.85 | 500 |
| 520 | 57.2 | 470.5 | 161.10 | 1.4 | 7.0 | 41.74 | 251.6 | 19.84 | 62.4 | 461.6 | 173.36 | 1.6 | 8.2 | 45.22 | 250.0 | 21.31 | 520 |
| 540 | 59.4 | 484.8 | 172.76 | 1.5 | 7.8 | 44.89 | 260.6 | 21.25 | 64.8 | 474.9 | 185.70 | 1.8 | 9.2 | 48.60 | 258.9 | 22.80 | 540 |
| 560 | 61.6 | 498.6 | 184.71 | 1.7 | 8.7 | 48.14 | 269.5 | 22.70 | 67.2 | 487.7 | 198.32 | 2.0 | 10.2 | 52.09 | 267.6 | 24.31 | 560 |
| 580 | 63.8 | 512.1 | 196.94 | 1.8 | 9.7 | 51.48 | 278.4 | 24.17 | 69.6 | 500.1 | 211.21 | 2.2 | 11.4 | 55.68 | 276.3 | 25.84 | 580 |
| 600 | 66.0 | 525.1 | 209.44 | 2.0 | 10.7 | 54.93 | 287.2 | 25.67 | 72.0 | 511.9 | 224.34 | 2.4 | 12.6 | 59.37 | 284.9 | 27.40 | 600 |
| 620 | 68.2 | 537.7 | 222.19 | 2.2 | 11.8 | 58.46 | 295.9 | 27.19 | 74.4 | 523.3 | 237.70 | 2.6 | 13.9 | 63.15 | 293.4 | 28.99 | 620 |
| 640 | 70.4 | 549.9 | 235.17 | 2.4 | 13.0 | 62.09 | 304.5 | 28.74 | 76.8 | 534.2 | 251.26 | 2.8 | 15.3 | 67.03 | 301.7 | 30.60 | 640 |
| 660 | 72.6 | 561.6 | 248.37 | 2.6 | 14.2 | 65.80 | 313.1 | 30.30 | 79.2 | 544.6 | 265.00 | 3.0 | 16.8 | 70.98 | 310.0 | 32.23 | 660 |
| 680 | 74.8 | 572.9 | 261.77 | 2.8 | 15.5 | 69.61 | 321.6 | 31.89 | 81.6 | 554.4 | 278.91 | 3.2 | 18.4 | 75.03 | 318.2 | 33.86 | 680 |
| 700 | 77.0 | 583.7 | 275.36 | 3.0 | 17.0 | 73.49 | 329.9 | 33.49 | 84.0 | 563.8 | 292.97 | 3.4 | 20.1 | 79.18 | 326.3 | 35.51 | 700 |

| $l_1$ | 26° Curve. | | | | | | | | 28° Curve. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 40 | 5.2 | 40.0 | 1.21 | | | .30 | 20 | .15 | 5.6 | 39.9 | 1.30 | | | .33 | 20 | .16 | 40 |
| 50 | 6.5 | 49.9 | 1.89 | | | .47 | 25 | .24 | 7.0 | 49.9 | 2.03 | | | .51 | 25 | .25 | 50 |
| 60 | 7.8 | 59.9 | 2.72 | | | .68 | 30 | .34 | 8.4 | 59.8 | 2.93 | | | .74 | 30 | .37 | 60 |
| 70 | 9.1 | 69.8 | 3.70 | | .01 | .93 | 35 | .46 | 9.8 | 69.8 | 3 99 | | .01 | 1.00 | 34.9 | .50 | 70 |
| 80 | 10.4 | 79.7 | 4.83 | .01 | 2 | 1.21 | 39.9 | .60 | 11.2 | 79.7 | 5.20 | .01 | 2 | 1.30 | 39.9 | .65 | 80 |
| 90 | 11.7 | 89.6 | 6.11 | 1 | 3 | 1.53 | 44.9 | .76 | 12.6 | 89.5 | 6.57 | 1 | 3 | 1.64 | 44.9 | .82 | 90 |
| 100 | 13.0 | 99.5 | 7.54 | 2 | 5 | 1.89 | 49.9 | .94 | 14.0 | 99.4 | 8.11 | 2 | 5 | 2.03 | 49.9 | 1.01 | 100 |
| 110 | 14.3 | 109.3 | 9.11 | 2 | 6 | 2.28 | 54.9 | 1.14 | 15.4 | 109.2 | 9.80 | 2 | 8 | 2.46 | 54.8 | 1.22 | 110 |
| 120 | 15.6 | 119.1 | 10.83 | 3 | 9 | 2.71 | 59.8 | 1.35 | 16.8 | 119.0 | 11.65 | 3 | .11 | 2.93 | 59.8 | 1.45 | 120 |
| 130 | 16.9 | 128.9 | 12.70 | 3 | .12 | 3.18 | 64.8 | 1.58 | 18.2 | 128.7 | 13.66 | 4 | .14 | 3.43 | 64 7 | 1.70 | 130 |
| 140 | 18.2 | 138.6 | 14.72 | 4 | .15 | 3.69 | 69.7 | 1.84 | 19.6 | 138 4 | 15.83 | 5 | .18 | 3.97 | 69.7 | 1.97 | 140 |
| 150 | 19.5 | 148.3 | 16.88 | 5 | .19 | 4.24 | 74.7 | 2.11 | 21.0 | 148.0 | 18.15 | 6 | .23 | 4.56 | 74.6 | 2.26 | 150 |
| 160 | 20.8 | 157.9 | 19.18 | 6 | .24 | 4.82 | 79.6 | 2.40 | 22.4 | 157.6 | 20.62 | .1 | .3 | 5.18 | 79.6 | 2.57 | 160 |
| 170 | 22.1 | 167.5 | 21.63 | 8 | .30 | 5.44 | 84.6 | 2.70 | 23.8 | 167.1 | 23.24 | .1 | .3 | 5.84 | 84.5 | 2.90 | 170 |
| 180 | 23.4 | 177.0 | 24.21 | 9 | .36 | 6.09 | 89.5 | 3.02 | 25.2 | 176.5 | 26.02 | .1 | .4 | 6.54 | 89.4 | 3.24 | 180 |
| 190 | 24.7 | 186 5 | 26.94 | .11 | .43 | 6.78 | 94.4 | 3.36 | 26.6 | 185.9 | 28.95 | .1 | .5 | 7.29 | 94.3 | 3.61 | 190 |
| 200 | 26.0 | 195.9 | 29.81 | .13 | .51 | 7.50 | 99.3 | 3.71 | 28.0 | 195.3 | 32.02 | .1 | .6 | 8.07 | 99.2 | 3.99 | 200 |
| 210 | 27.3 | 205.3 | 32 81 | .2 | .6 | 8.26 | 104.2 | 4.09 | 29.4 | 204.6 | 35.25 | .2 | .7 | 8.89 | 104.1 | 4.39 | 210 |
| 220 | 28.6 | 214.6 | 35.95 | .2 | .7 | 9.06 | 109.1 | 4.48 | 30.8 | 213.7 | 38.61 | .2 | .8 | 9.75 | 108.9 | 4.81 | 220 |
| 230 | 29.9 | 223.8 | 39.23 | .2 | .8 | 9.90 | 113.9 | 4.89 | 32.2 | 222.8 | 42.12 | .2 | .9 | 10.64 | 113.8 | 5.24 | 230 |
| 240 | 31.2 | 233.0 | 42.61 | .2 | .9 | 10.77 | 118.8 | 5.31 | 33.6 | 231.9 | 45.77 | .3 | 1.0 | 11.58 | 118.6 | 5.69 | 240 |
| 250 | 32.5 | 242.1 | 46.19 | .2 | 1.0 | 11.67 | 123.7 | 5.75 | 35.0 | 240.8 | 49.56 | .3 | 1.2 | 12.55 | 123.4 | 6.16 | 250 |
| 260 | 33.8 | 251.1 | 49.87 | .3 | 1.1 | 12.61 | 128.5 | 6.20 | 36.4 | 249.7 | 53.49 | .3 | 1.4 | 13.56 | 128.2 | 6.64 | 260 |
| 270 | 35.1 | 260.0 | 53.67 | .3 | 1.3 | 13.59 | 133.3 | 6.67 | 37.8 | 258.5 | 57.55 | .4 | 1.5 | 14.61 | 133.0 | 7.14 | 270 |
| 280 | 36.4 | 268.9 | 57.60 | .3 | 1.5 | 14.60 | 138.1 | 7.16 | 39.2 | 267.2 | 61.75 | .4 | 1.7 | 15.69 | 137.8 | 7.66 | 280 |
| 290 | 37.7 | 277.7 | 61.66 | .4 | 1.6 | 15.65 | 142.9 | 7.66 | 40.6 | 275.8 | 66.07 | .4 | 1.9 | 16.81 | 142.6 | 8.20 | 290 |
| 300 | 39.0 | 286.4 | 65.85 | .4 | 1.8 | 16.73 | 147.7 | 8.17 | 42.0 | 284.3 | 70.53 | .5 | 2.1 | 17.97 | 147.3 | 8.75 | 300 |
| 310 | 40.3 | 295.0 | 70.16 | .5 | 2.0 | 17.85 | 152.4 | 8.70 | 43.4 | 292.7 | 75.12 | .5 | 2.3 | 19.16 | 152.1 | 9.31 | 310 |
| 320 | 41.6 | 303.5 | 74.58 | .5 | 2.2 | 19.00 | 157.2 | 9.25 | 44.8 | 301.0 | 79.83 | .5 | 2.6 | 20.39 | 156.8 | 9.89 | 320 |
| 330 | 42.9 | 312.0 | 79.12 | .6 | 2.4 | 20.18 | 161.9 | 9.81 | 46.2 | 309.2 | 84.66 | .6 | 2.8 | 21.66 | 161.5 | 10.48 | 330 |
| 340 | 44.2 | 320.3 | 83.78 | .6 | 2.6 | 21.39 | 166.7 | 10.38 | 47.6 | 317.3 | 89 61 | .6 | 3.1 | 22.96 | 166.1 | 11.09 | 340 |
| 350 | 45.5 | 328.5 | 88.55 | .7 | 2.9 | 22 64 | 171.4 | 10.97 | 49.0 | 325.2 | 94.68 | .7 | 3.4 | 24.29 | 170.8 | 11.71 | 350 |
| 360 | 46.8 | 336.7 | 93.44 | .7 | 3.1 | 23.92 | 176.1 | 11.57 | 50.4 | 333.1 | 99 86 | .8 | 3.7 | 25.66 | 175.4 | 12.34 | 360 |
| 370 | 48.1 | 344.8 | 98.44 | .7 | 3.4 | 25.23 | 180.8 | 12.18 | 51.8 | 340.9 | 105.16 | .9 | 4.0 | 27.07 | 180.0 | 12.99 | 370 |

| $l_1$ | 32° Curve. | | | | | | | | 36° Curve. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 30 | 4.8 | 30 | .84 | | | .21 | 15 | .10 | 5.4 | 30 | .94 | | | .24 | 15 | .12 | 30 |
| 40 | 6.4 | 39.9 | 1.49 | | | .37 | 20 | .18 | 7.2 | 39.9 | 1.67 | | | .42 | 20 | .21 | 40 |
| 50 | 8.0 | 49.9 | 2.32 | | .01 | .58 | 25 | .29 | 9.0 | 49.9 | 2.61 | | .01 | .65 | 25 | .32 | 50 |
| 60 | 9.6 | 59.8 | 3.35 | .01 | 2 | .84 | 30 | .42 | 10.8 | 59.8 | 3.76 | .01 | 2 | .94 | 30 | .47 | 60 |
| 70 | 11.2 | 69.7 | 4.55 | 1 | 3 | 1.14 | 34.9 | .57 | 12.6 | 69.7 | 5.11 | 1 | 4 | 1.28 | 34.9 | .64 | 70 |
| 80 | 12.8 | 79.6 | 5.94 | 1 | 5 | 1.49 | 39.9 | .74 | 14.4 | 79.5 | 6.67 | 1 | 6 | 1.67 | 39.9 | .83 | 80 |
| 90 | 14.4 | 89.4 | 7.50 | 2 | 7 | 1.88 | 44.9 | .94 | 16.2 | 89.3 | 8.43 | 2 | 9 | 2.11 | 44.9 | 1.05 | 90 |
| 100 | 16.0 | 99.2 | 9.25 | 2 | .10 | 2.32 | 49.9 | 1.16 | 18.0 | 99.0 | 10.40 | 3 | .13 | 2.61 | 49.8 | 1.30 | 100 |
| 110 | 17.6 | 109.0 | 11.18 | 3 | .13 | 2.80 | 54.8 | 1.39 | 19.8 | 108.7 | 12.56 | 4 | .16 | 3.15 | 54.8 | 1.57 | 110 |
| 120 | 19.2 | 118.7 | 13.29 | 4 | .17 | 3.34 | 59.8 | 1.66 | 21.6 | 118.3 | 14.92 | 5 | .22 | 3.75 | 59.7 | 1.86 | 120 |
| 130 | 20.8 | 128.3 | 15.58 | 5 | .21 | 3.91 | 64.7 | 1.94 | 23.4 | 127.8 | 17.48 | 6 | .28 | 4.39 | 64.6 | 2.18 | 130 |
| 140 | 22.4 | 137.9 | 18.04 | 7 | .25 | 4.53 | 69.6 | 2.25 | 25.2 | 137.3 | 20.24 | 8 | .35 | 5.09 | 69.5 | 2.52 | 140 |
| 150 | 24.0 | 147.4 | 20.68 | 8 | .31 | 5.20 | 74.5 | 2.58 | 27.0 | 146.7 | 23.19 | .10 | .44 | 5.84 | 74.4 | 2.89 | 150 |
| 160 | 25.6 | 156.8 | 23.49 | .1 | .4 | 5.91 | 79.4 | 2.93 | 28.8 | 156.0 | 26.33 | .1 | .5 | 6.63 | 79.3 | 3.28 | 160 |
| 170 | 27.2 | 166.2 | 26.47 | .1 | .5 | 6.67 | 84.3 | 3.30 | 30.6 | 165.2 | 29.65 | .1 | .6 | 7.48 | 84.2 | 3.69 | 170 |
| 180 | 28.8 | 175.5 | 29.62 | .1 | .6 | 7.46 | 89.2 | 3.69 | 32.4 | 174.3 | 33.16 | .2 | .7 | 8.38 | 89.0 | 4.12 | 180 |
| 190 | 30.4 | 184.7 | 32.93 | .2 | .7 | 8.31 | 94.1 | 4.10 | 34.2 | 183.3 | 36.85 | .2 | .9 | 9.32 | 93.9 | 4.58 | 190 |
| 200 | 32.0 | 193.8 | 36.41 | .2 | .8 | 9.20 | 98.9 | 4.53 | 36.0 | 192.2 | 40.72 | .2 | 1.0 | 10.31 | 98.7 | 5.06 | 200 |
| 210 | 33.6 | 202.9 | 40.05 | .2 | .9 | 10.13 | 103.8 | 4.98 | 37.8 | 201.0 | 44.75 | .3 | 1.2 | 11.35 | 103.5 | 5.56 | 210 |
| 220 | 35.2 | 211.8 | 43.85 | .3 | 1.1 | 11.10 | 108.6 | 5.45 | 39.6 | 209.7 | 48.97 | .3 | 1.4 | 12.44 | 108.2 | 6.08 | 220 |
| 230 | 36.8 | 220.7 | 47.81 | .3 | 1.2 | 12.12 | 113.4 | 5.94 | 41.4 | 218.3 | 53.36 | .3 | 1.6 | 13.58 | 113.0 | 6.62 | 230 |
| 240 | 38.4 | 229.4 | 51.92 | .3 | 1.4 | 13.19 | 118.2 | 6.45 | 43.2 | 226.7 | 57.92 | .4 | 1.8 | 14.77 | 117.7 | 7.18 | 240 |
| 250 | 40.0 | 238.1 | 56.19 | .4 | 1.6 | 14.29 | 123.0 | 6.97 | 45.0 | 235.0 | 62.62 | .4 | 2.0 | 16.00 | 122.5 | 7.70 | 250 |
| 260 | 41.6 | 246.6 | 60.60 | .4 | 1.8 | 15.43 | 127.7 | 7.52 | 46.8 | 243.2 | 67.48 | .5 | 2.3 | 17.27 | 127.1 | 8.36 | 260 |
| 270 | 43.2 | 255.0 | 65.15 | .4 | 2.0 | 16.62 | 132.5 | 8.08 | 48.6 | 251.2 | 72.50 | .5 | 2.6 | 18.59 | 131.8 | 8.97 | 270 |
| 280 | 44.8 | 263.3 | 69.85 | .5 | 2.3 | 17.84 | 137.2 | 8.66 | 50.4 | 259.1 | 77.67 | .6 | 2.9 | 19.96 | 136.4 | 9.60 | 280 |
| 290 | 46.4 | 271.5 | 74.69 | .5 | 2.5 | 19.11 | 141.9 | 9.25 | 52.2 | 266.8 | 82.98 | .6 | 3.2 | 21.37 | 141.1 | 10.25 | 290 |
| 300 | 48.0 | 279.6 | 79.67 | .6 | 2.8 | 20.42 | 146.5 | 9.86 | 54.0 | 274.4 | 88.43 | .7 | 3.5 | 22.82 | 145.7 | 10.92 | 300 |
| 310 | 49.6 | 287.5 | 84.78 | .6 | 3.1 | 21.76 | 151.2 | 10.48 | 55.8 | 281.9 | 94.02 | .8 | 3.9 | 24.31 | 150.2 | 11.60 | 310 |
| 320 | 51.2 | 295.4 | 90.01 | .7 | 3.4 | 23.15 | 155.8 | 11.12 | 57.6 | 289.2 | 99.73 | .8 | 4.3 | 25.85 | 154.8 | 12.30 | 320 |
| 330 | 52.8 | 303.1 | 95.38 | .8 | 3.7 | 24.57 | 160.4 | 11.77 | 59.4 | 296.3 | 105.57 | .9 | 4.7 | 27.42 | 159.3 | 13.00 | 330 |
| 340 | 54.4 | 310.6 | 100.87 | .8 | 4.1 | 26.04 | 165.0 | 12.44 | 61.2 | 303.2 | 111.54 | 1.0 | 5.1 | 29.04 | 163.8 | 13.72 | 340 |
| 350 | 56.0 | 318.0 | 106.48 | .9 | 4.5 | 27.54 | 169.5 | 13.12 | 63.0 | 310.0 | 117.64 | 1.1 | 5.6 | 30.70 | 168.2 | 14.46 | 350 |
| 360 | 57.6 | 325.3 | 112.20 | 1.0 | 4.9 | 29.08 | 174.1 | 13.82 | 64.8 | 316.7 | 123.85 | 1.2 | 6.1 | 32.40 | 172.6 | 15.21 | 360 |

| $l_1$ | 40° CURVE. | | | | | | | | 44° CURVE. | | | | | | | | $l_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I^\circ$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I^\circ$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | |
| 30 | 6.0 | 30 | 1.05 | | | .26 | 15 | .13 | 6.6 | 29.9 | 1.15 | | | .29 | 15 | .14 | 30 |
| 40 | 8.0 | 39.9 | 1.86 | | | .46 | 20 | .23 | 8.8 | 39.9 | 2.04 | | | .51 | 20 | .25 | 40 |
| 50 | 10.0 | 49.8 | 2.90 | | .01 | .73 | 25 | .36 | 11.0 | 49.8 | 3.19 | | .01 | .80 | 25 | .40 | 50 |
| 60 | 12.0 | 59.7 | 4.17 | .01 | 3 | 1.04 | 29.9 | .52 | 13.2 | 59.7 | 4.59 | .01 | 3 | 1.15 | 29.9 | .57 | 60 |
| 70 | 14.0 | 69.6 | 5.68 | 1 | 5 | 1.42 | 34.9 | .71 | 15.4 | 69.5 | 6.24 | 1 | 6 | 1.56 | 34.9 | .78 | 70 |
| 80 | 16.0 | 79.4 | 7.40 | 2 | 7 | 1.86 | 39.9 | .93 | 17.6 | 79.2 | 8.14 | 2 | 9 | 2.04 | 39.9 | 1.02 | 80 |
| 90 | 18.0 | 89.1 | 9.36 | 3 | .11 | 2.35 | 44.8 | 1.17 | 19.8 | 88.9 | 10.28 | 3 | .13 | 2 58 | 44.8 | 1.28 | 90 |
| 100 | 20.0 | 98.8 | 11.53 | 4 | .15 | 2.89 | 49.8 | 1.44 | 22.0 | 98.5 | 12.66 | 4 | .18 | 3.18 | 49.7 | 1.58 | 100 |
| 110 | 22.0 | 108.4 | 13.93 | 5 | .20 | 3.50 | 54.7 | 1.74 | 24.2 | 108.0 | 15.29 | 6 | .25 | 3.84 | 54.7 | 1.90 | 110 |
| 120 | 24.0 | 117.9 | 16.54 | 6 | .27 | 4.16 | 59.7 | 2.06 | 26.4 | 117.5 | 18.15 | 8 | .32 | 4.56 | 59.5 | 2.26 | 120 |
| 130 | 26.0 | 127.3 | 19.37 | 8 | .35 | 4.87 | 64.5 | 2.41 | 28.6 | 126.8 | 21.25 | .10 | .41 | 5.35 | 64.5 | 2.65 | 130 |
| 140 | 28.0 | 136.7 | 22.42 | .10 | 44 | 5.65 | 69.4 | 2.79 | 30.8 | 136.0 | 24.57 | .12 | .52 | 6.21 | 69.3 | 3.06 | 140 |
| 150 | 30.0 | 145.9 | 25.67 | .13 | .53 | 6.48 | 74.3 | 3.19 | 33.0 | 145.1 | 28.12 | .14 | .65 | 7.11 | 74.2 | 3.50 | 150 |
| 160 | 32.0 | 155.1 | 29.13 | .2 | .6 | 7.36 | 79.2 | 3.62 | 35.2 | 154.1 | 31.89 | .2 | .8 | 8.08 | 79.0 | 3.97 | 160 |
| 170 | 34.0 | 164.1 | 32.79 | .2 | .8 | 8.30 | 84.0 | 4.08 | 37.4 | 162.9 | 35.88 | .2 | .9 | 9.10 | 83.8 | 4.46 | 170 |
| 180 | 36.0 | 173.0 | 36.65 | .2 | 1.0 | 9.29 | 88.8 | 4.55 | 39.6 | 171.6 | 40.07 | .2 | 1.1 | 10.19 | 88.6 | 4.97 | 180 |
| 190 | 38.0 | 181.8 | 40.70 | .2 | 1.1 | 10.33 | 93.6 | 5.05 | 41.8 | 180.1 | 44.47 | .3 | 1.3 | 11.33 | 93.3 | 5.51 | 190 |
| 200 | 40.0 | 190.4 | 44.95 | .3 | 1.3 | 11.43 | 98.4 | 5.58 | 44.0 | 188.5 | 49.07 | .3 | 1.6 | 12.52 | 98.0 | 6.08 | 200 |
| 210 | 42.0 | 199.0 | 49.38 | .3 | 1.5 | 12.58 | 103.1 | 6.12 | 46.2 | 196.7 | 53.87 | .4 | 1.8 | 13.78 | 102.7 | 6.67 | 210 |
| 220 | 44.0 | 207.4 | 53.99 | .4 | 1.7 | 13.78 | 107.8 | 6.69 | 48.4 | 204.8 | 58.86 | .4 | 2.1 | 15.09 | 107.4 | 7.28 | 220 |
| 230 | 46.0 | 215.6 | 58.77 | .4 | 2.0 | 15 03 | 112.5 | 7.28 | 50.6 | 212.7 | 64.02 | .5 | 2.4 | 16.46 | 112.0 | 7.91 | 230 |
| 240 | 48.0 | 223.7 | 63.73 | .5 | 2.2 | 16.33 | 117.2 | 7.88 | 52.8 | 220.4 | 69.36 | .5 | 2.8 | 17.87 | 116.6 | 8.56 | 240 |
| 250 | 50.0 | 231.6 | 68.85 | .5 | 2.5 | 17.68 | 121.9 | 8.51 | 55.0 | 227.9 | 74.87 | .6 | 3.1 | 19.34 | 121.2 | 9.23 | 250 |
| 260 | 52.0 | 239.4 | 74.14 | .6 | 2.8 | 19.08 | 126.5 | 9.15 | 57.2 | 235.2 | 80.55 | .7 | 3.5 | 20.87 | 125.8 | 9.92 | 260 |
| 270 | 54.0 | 247.0 | 79.58 | .6 | 3.2 | 20.53 | 131.1 | 9.81 | 59.4 | 242.4 | 86.38 | .7 | 3.9 | 22.45 | 130.3 | 10.62 | 270 |
| 280 | 56.0 | 254.4 | 85.18 | .7 | 3.6 | 22.03 | 135.6 | 10.49 | 61.6 | 249.3 | 92.35 | .8 | 4.3 | 24.07 | 134.8 | 11.35 | 280 |
| 290 | 58.0 | 261.6 | 90.92 | .8 | 4.0 | 23 58 | 140.2 | 11.19 | 63.8 | 256.0 | 98.47 | .9 | 4.8 | 25.74 | 139.2 | 12.08 | 290 |
| 300 | 60.0 | 268.7 | 96.79 | .9 | 4.4 | 25.17 | 144.7 | 11.90 | 66.0 | 262.5 | 104.72 | 1.0 | 5.3 | 27.46 | 143.6 | 12.83 | 300 |
| 310 | 62.0 | 275.6 | 102.80 | .9 | 4.9 | 26.80 | 149.1 | 12.63 | 68.2 | 268.8 | 111.09 | 1.1 | 5.9 | 29.23 | 147.9 | 13.59 | 310 |
| 320 | 64.0 | 282.3 | 108.94 | 1.0 | 5.3 | 28.48 | 153.6 | 13.37 | 70.4 | 274.9 | 117.58 | 1.2 | 6.5 | 31.05 | 152.2 | 14.37 | 320 |
| 330 | 66.0 | 288.8 | 115.19 | 1.1 | 5.8 | 30.20 | 158.0 | 14.12 | 72.6 | 280.8 | 124.18 | 1.3 | 7.1 | 32.90 | 156.5 | 15.15 | 330 |
| 340 | 68.0 | 295.1 | 121.56 | 1.2 | 6.4 | 31.97 | 162.3 | 14.88 | 74.8 | 286.4 | 130.88 | 1.4 | 7 8 | 34.80 | 160.8 | 15.94 | 340 |
| 350 | 70.0 | 301.2 | 128.03 | 1.3 | 7.0 | 33.78 | 166.6 | 15.66 | 77.0 | 291.8 | 137.68 | 1 5 | 8.5 | 36.74 | 165.0 | 16.74 | 350 |
| 360 | 72.0 | 307.2 | 134.61 | 1.4 | 7.6 | 35.63 | 170.9 | 16.45 | 79.2 | 297.0 | 144.57 | 1.6 | 9.3 | 38.74 | 169.1 | 17.55 | 360 |

|  | 48° CURVE. |  |  |  |  |  |  |  | 52° CURVE. |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $l_1$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $l_1$ |
| 30 | 7.2 | 29.9 | 1.25 |  |  | .32 | 15 | .16 | 7.8 | 29.9 | 1.36 |  |  | .34 | 15 | 0.17 | 30 |
| 40 | 9.6 | 39.9 | 2.28 |  | .01 | .56 | 20 | .28 | 10.4 | 39.9 | 2.42 |  | .01 | .60 | 20 | .30 | 40 |
| 50 | 12.0 | 49.8 | 3.48 | .01 | 2 | .87 | 25 | .48 | 13.0 | 49.7 | 3.77 | .01 | 2 | .94 | 25 | .47 | 50 |
| 60 | 14.4 | 59.6 | 5.00 | 1 | 4 | 1.25 | 29.9 | .62 | 15.6 | 59.5 | 5.42 | 1 | 4 | 1.36 | 29.9 | .68 | 60 |
| 70 | 16.8 | 69.4 | 6.80 | 2 | 7 | 1.70 | 34.9 | .85 | 18.2 | 69.3 | 7.36 | 2 | 8 | 1.85 | 34.9 | .92 | 70 |
| 80 | 19.2 | 79.1 | 8.87 | 3 | .11 | 2.22 | 39.8 | 1.11 | 20.8 | 78.9 | 9.59 | 3 | .12 | 2.41 | 39.8 | 1.20 | 80 |
| 90 | 21.6 | 88.7 | 11.19 | 4 | .15 | 2.81 | 44.8 | 1.40 | 23.4 | 88.5 | 12.11 | 5 | .18 | 3.04 | 44.7 | 1.51 | 90 |
| 100 | 24.0 | 98.2 | 13.79 | 5 | .22 | 3.47 | 49.7 | 1.72 | 26.0 | 97.9 | 14.90 | 6 | .26 | 3.75 | 49.6 | 1.86 | 100 |
| 110 | 26.4 | 107.7 | 16.64 | 7 | .29 | 4.19 | 54.6 | 2.07 | 28.6 | 107.3 | 17.98 | .1 | .3 | 4.53 | 54.5 | 2.24 | 110 |
| 120 | 28.8 | 117.0 | 19.74 | 9 | .38 | 4.98 | 59.5 | 2.46 | 31.2 | 116.5 | 21.32 | .1 | .4 | 5.38 | 59.4 | 2.65 | 120 |
| 130 | 31.2 | 126.2 | 23.10 | .11 | .49 | 5.83 | 64.3 | 2.87 | 33.8 | 125.5 | 24.93 | .1 | .6 | 6.31 | 64.2 | 3.10 | 130 |
| 140 | 33.6 | 135.2 | 26.70 | .14 | .62 | 6.75 | 69.2 | 3.32 | 36.4 | 134.4 | 28.80 | .2 | .7 | 7.30 | 69.1 | 3.58 | 140 |
| 150 | 36.0 | 144.2 | 30.54 | .17 | .77 | 7.74 | 74.0 | 3.79 | 39.0 | 143.2 | 32.92 | .2 | .9 | 8.37 | 73.8 | 4.09 | 150 |
| 160 | 38.4 | 153.0 | 34.61 | .2 | .9 | 8.79 | 78.8 | 4.30 | 41.6 | 151.8 | 37.29 | .3 | 1.1 | 9.50 | 78.6 | 4.62 | 160 |
| 170 | 40.8 | 161.6 | 38.91 | .2 | 1.1 | 9.90 | 83.6 | 4.83 | 44.2 | 160.1 | 41.89 | .3 | 1.3 | 10.70 | 83.3 | 5.19 | 170 |
| 180 | 43.2 | 170.0 | 43.43 | .3 | 1.3 | 11.07 | 88.3 | 5.39 | 46.8 | 168.3 | 46.72 | .4 | 1.6 | 11.96 | 88.0 | 5.79 | 180 |

|  | 56° CURVE. |  |  |  |  |  |  |  | 60° CURVE. |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $l_1$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $I°$ | $x_1$ | $y_1$ | $e$ | $e'$ | $F$ | $x'$ | $y'$ | $l_1$ |
| 30 | 8.4 | 29.9 | 1.46 |  |  | .37 | 15 | .18 | 9.0 | 29.9 | 1.57 |  | .01 | .39 | 15 | .20 | 30 |
| 40 | 11.2 | 39.8 | 2.60 |  | .01 | .65 | 20 | .32 | 12.0 | 39.8 | 2.78 | .01 | 2 | .70 | 20 | .35 | 40 |
| 50 | 14.0 | 49.7 | 4.06 | .01 | 2 | 1.02 | 24.9 | .51 | 15.0 | 49.7 | 4.34 | 1 | 4 | 1.09 | 24.9 | .54 | 50 |
| 60 | 16.8 | 59.5 | 5.83 | 2 | 5 | 1.46 | 29.9 | .73 | 18.0 | 59.4 | 6.24 | 2 | 7 | 1.57 | 29.9 | .78 | 60 |
| 70 | 19.6 | 69.2 | 7.92 | 3 | 9 | 1.99 | 34.9 | .99 | 21.0 | 69.1 | 8.47 | 3 | .12 | 2.13 | 34.8 | 1.06 | 70 |
| 80 | 22.4 | 78.8 | 10.31 | 4 | .15 | 2.59 | 39.8 | 1.29 | 24.0 | 78.6 | 11.03 | 4 | .18 | 2.77 | 39.8 | 1.37 | 80 |
| 90 | 25.2 | 88.3 | 13.01 | 5 | .21 | 3.27 | 44.7 | 1.62 | 27.0 | 88.0 | 13.91 | 6 | .25 | 3.50 | 44.7 | 1.73 | 90 |
| 100 | 28.0 | 97.6 | 16.01 | 6 | .30 | 4.03 | 49.6 | 1.99 | 30.0 | 97.3 | 17.12 | 8 | .35 | 4.32 | 49.5 | 2.13 | 100 |
| 110 | 30.8 | 106.9 | 19.31 | .1 | .4 | 4.87 | 54.5 | 2.40 | 33.0 | 106.4 | 20.62 | .1 | .5 | 5.21 | 54.4 | 2.57 | 110 |
| 120 | 33.6 | 116.0 | 22.89 | .1 | .5 | 5.79 | 59.3 | 2.85 | 36.0 | 115.3 | 24.43 | .1 | .6 | 6.19 | 59.2 | 3.04 | 120 |
| 130 | 36.4 | 124.9 | 26.75 | .2 | .7 | 6.78 | 64.1 | 3.32 | 39.0 | 124.1 | 28.53 | .2 | .8 | 7.25 | 64.0 | 3.54 | 130 |
| 140 | 39.2 | 133.6 | 30.88 | .2 | .9 | 7.85 | 68.9 | 3.83 | 42.0 | 132.7 | 32.92 | .2 | 1.0 | 8.38 | 68.8 | 4.08 | 140 |
| 150 | 42.0 | 142.2 | 35.27 | .2 | 1.2 | 8.98 | 73.7 | 4.37 | 45.0 | 141.0 | 37.58 | .2 | 1.2 | 9.60 | 73.5 | 4.65 | 150 |
| 160 | 44.8 | 150.5 | 39.92 | .3 | 1.3 | 10.20 | 78.4 | 4.95 | 48.0 | 149.1 | 42.49 | .3 | 1.5 | 10.89 | 78.2 | 5.26 | 160 |
| 170 | 47.6 | 158.6 | 44.81 | .3 | 1.5 | 11.48 | 83.1 | 5.55 | 51.0 | 157.0 | 47.65 | .4 | 1.8 | 12.26 | 72.8 | 5.89 | 170 |
| 180 | 50.4 | 166.6 | 49.93 | .4 | 1.8 | 12.83 | 87.7 | 6.17 | 54.0 | 164.7 | 53.06 | .4 | 2.1 | 13.69 | 67.4 | 6.55 | 180 |

# TABLE XVII.—AREAS OF LEVEL SECTIONS.

Base, 2*b* = 14 feet. Side slopes 1½ to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 1.4 | 2.9 | 4.3 | 5.8 | 7.4 | 8.9 | 10.5 | 12.2 | 13.8 |
| 1 | 15.5 | 17.2 | 19.0 | 20.7 | 22.5 | 24.4 | 26.2 | 28.1 | 30.1 | 32.0 |
| 2 | 34.0 | 36.0 | 38.1 | 40.1 | 42.2 | 44.4 | 46.5 | 48.7 | 51.0 | 53.2 |
| 3 | 55.5 | 57.8 | 60.2 | 62.5 | 64.9 | 67.4 | 69.8 | 72.3 | 74.9 | 77.4 |
| 4 | 80.0 | 82.6 | 85.3 | 87.9 | 90.6 | 93.4 | 96.1 | 98.9 | 101.8 | 104.6 |
| 5 | 107.5 | 110.4 | 113.4 | 116.3 | 119.3 | 122.4 | 125.4 | 128.5 | 131.7 | 134.8 |
| 6 | 138.0 | 141.2 | 144.5 | 147.7 | 151.0 | 154.4 | 157.7 | 161.1 | 164.6 | 168.0 |
| 7 | 171.5 | 175.0 | 178.6 | 182.1 | 185.7 | 189.4 | 193.0 | 196.7 | 200.5 | 204.2 |
| 8 | 208.0 | 211.8 | 215.7 | 219.5 | 223.4 | 227.4 | 231.3 | 235.3 | 239.4 | 243.4 |
| 9 | 247.5 | 251.6 | 255.8 | 259.9 | 264.1 | 268.4 | 272.6 | 276.9 | 281.3 | 285.6 |
| 10 | 290.0 | 294.4 | 298.9 | 303.3 | 307.8 | 312.4 | 316.9 | 321.7 | 326.2 | 330.8 |
| 11 | 335.5 | 340.2 | 345.0 | 349.7 | 354.5 | 359.4 | 364.2 | 369.1 | 374.1 | 379.0 |
| 12 | 384.0 | 389.0 | 394.1 | 399.1 | 404.2 | 409.4 | 414.5 | 419.7 | 425.0 | 430.2 |
| 13 | 435.5 | 440.8 | 446.2 | 451.5 | 456.9 | 462.4 | 467.8 | 473.3 | 478.9 | 484.4 |
| 14 | 490.0 | 495.6 | 501.3 | 506.9 | 512.6 | 518.4 | 524.1 | 529.9 | 535.8 | 541.6 |
| 15 | 547.5 | 553.4 | 559.4 | 565.3 | 571.3 | 577.4 | 583.4 | 589.5 | 595.7 | 601 8 |
| 16 | 608.0 | 614.2 | 620.5 | 626.7 | 633.0 | 639.4 | 645.7 | 652.1 | 658.6 | 665.0 |
| 17 | 671.5 | 678.0 | 684.6 | 691.1 | 697.7 | 704.4 | 711.0 | 717.7 | 724.5 | 731.2 |
| 18 | 738.0 | 744.8 | 751.7 | 758.5 | 765.4 | 772.4 | 779.3 | 786.3 | 793.4 | 800.4 |
| 19 | 807.5 | 814.6 | 821.8 | 828.9 | 836.1 | 843.4 | 850.6 | 857.9 | 865.3 | 872.6 |
| 20 | 880.0 | 887.4 | 894.9 | 902.3 | 909.8 | 917.4 | 924.9 | 932.5 | 940.2 | 947.8 |
| 21 | 955.5 | 963.2 | 971.0 | 978.7 | 986.5 | 994.4 | 1002.2 | 1010.1 | 1018.1 | 1026.0 |
| 22 | 1034.0 | 1042.0 | 1050.1 | 1058.1 | 1066.2 | 1074.4 | 1082.5 | 1090.7 | 1099.0 | 1107.2 |
| 23 | 1115.5 | 1123.8 | 1132.2 | 1140.5 | 1148.9 | 1157.4 | 1165.8 | 1174.3 | 1182.9 | 1191.4 |
| 24 | 1200.0 | 1208 6 | 1217.3 | 1225.9 | 1234.6 | 1243.4 | 1252.1 | 1260.9 | 1269.8 | 1278.6 |
| 25 | 1287.5 | 1296.4 | 1305.4 | 1314.3 | 1323.3 | 1332.4 | 1341.4 | 1350.5 | 1359.7 | 1368.8 |
| 26 | 1378.0 | 1387.2 | 1396.5 | 1405.7 | 1415.0 | 1424.4 | 1433.7 | 1443.1 | 1452.6 | 1462 0 |
| 27 | 1471.5 | 1481.0 | 1490 6 | 1500.1 | 1509.7 | 1519.4 | 1529.0 | 1538.7 | 1548.5 | 1558.2 |
| 28 | 1568.0 | 1577.8 | 1587.7 | 1597.5 | 1607.4 | 1617 4 | 1627.3 | 1637.3 | 1647.4 | 1657.4 |
| 29 | 1667.5 | 1677.6 | 1687.8 | 1697.9 | 1708.1 | 1718.4 | 1728.6 | 1738.9 | 1749.3 | 1759.6 |

Base, 2*b* = 15 feet. Side slopes 1½ to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 1.5 | 3.1 | 4.6 | 6.2 | 7.9 | 9.5 | 11.2 | 13.0 | 14.7 |
| 1 | 16 5 | 18.3 | 20.2 | 22.0 | 23.9 | 25.9 | 27.8 | 29.8 | 31.9 | 33.9 |
| 2 | 36.0 | 38.1 | 40.3 | 42.4 | 44.6 | 46.9 | 49.1 | 51.4 | 53.8 | 56.1 |
| 3 | 58.5 | 60.9 | 63.4 | 65.8 | 68.3 | 70.9 | 73.4 | 76.0 | 78.7 | 81.3 |
| 4 | 84.0 | 86.7 | 89.5 | 92.2 | 95.0 | 97.9 | 100.7 | 103.6 | 106.6 | 109.5 |
| 5 | 112.5 | 115.5 | 118.6 | 121.6 | 124.7 | 127.9 | 131.0 | 134.2 | 137.5 | 140.7 |
| 6 | 144.0 | 147.3 | 150.7 | 154.0 | 157.4 | 160.9 | 164.3 | 167.8 | 171.4 | 174.9 |
| 7 | 178 5 | 182.1 | 185.8 | 189.4 | 193.1 | 196.9 | 200.6 | 204.4 | 208.3 | 212.1 |
| 8 | 216.0 | 219.9 | 223.9 | 227.8 | 231.8 | 235.9 | 239.9 | 244.0 | 248.2 | 252.3 |
| 9 | 256.5 | 260.7 | 265.0 | 269.2 | 273.5 | 277.9 | 282.2 | 286.6 | 291.1 | 295.5 |
| 10 | 300.0 | 304.5 | 309.1 | 313.6 | 318.2 | 322.9 | 327.5 | 332.2 | 337.0 | 341.7 |
| 11 | 346 5 | 351.3 | 356.2 | 361.0 | 365.9 | 370 9 | 375.8 | 380.8 | 385.9 | 390.9 |
| 12 | 396.0 | 401.1 | 406.3 | 411.4 | 416.6 | 421.9 | 427.1 | 432.4 | 437.8 | 443.1 |
| 13 | 448.5 | 453.9 | 459.4 | 464.8 | 470.3 | 475.9 | 481.4 | 487.0 | 492.7 | 498.3 |
| 14 | 504.0 | 509.7 | 515.5 | 521.2 | 527.0 | 532.9 | 538.7 | 544.6 | 550.6 | 556.5 |
| 15 | 562.5 | 568.5 | 574.6 | 580.6 | 586.7 | 592.9 | 599.0 | 605.2 | 611.5 | 617 7 |
| 16 | 624.0 | 630.3 | 636.7 | 643.0 | 649.4 | 655.9 | 662.3 | 668.8 | 675.4 | 681.9 |
| 17 | 688 5 | 695.1 | 701.8 | 708.4 | 715.1 | 721.9 | 728.6 | 735.4 | 742.3 | 749.1 |
| 18 | 756.0 | 762.9 | 769.9 | 776 8 | 783.8 | 790 9 | 797.9 | 805.0 | 812.2 | 819.3 |
| 19 | 826.5 | 833.7 | 841.0 | 848.2 | 855.5 | 862 9 | 870.2 | 877.6 | 885.1 | 892.5 |
| 20 | 900.0 | 907.5 | 915.1 | 922.6 | 930.2 | 937.9 | 945.5 | 953.2 | 961.0 | 968.7 |
| 21 | 976.5 | 984.3 | 992.2 | 1000.0 | 1007.9 | 1015 9 | 1023.8 | 1031.8 | 1039.9 | 1047.9 |
| 22 | 1056.0 | 1064.1 | 1072.3 | 1080.4 | 1088.6 | 1096 9 | 1105.1 | 1113.4 | 1121.8 | 1130 1 |
| 23 | 1138.5 | 1146.9 | 1155.4 | 1163.8 | 1172.3 | 1180.9 | 1189.4 | 1178.0 | 1206.7 | 1215.3 |
| 24 | 1224.0 | 1232.7 | 1241.5 | 1250.2 | 1259.0 | 1267.9 | 1276.7 | 1285.6 | 1294.6 | 1303.5 |
| 25 | 1312.5 | 1321.5 | 1330.6 | 1339.6 | 1348.7 | 1357.9 | 1367.0 | 1376.2 | 1385.5 | 1394.7 |
| 26 | 1404.0 | 1413.3 | 1422.7 | 1432.0 | 1441.4 | 1450.9 | 1460 3 | 1469.8 | 1479.4 | 1488.9 |
| 27 | 1498.5 | 1508.1 | 1517.8 | 1527.4 | 1537.1 | 1546.9 | 1556.6 | 1566.4 | 1576.3 | 1586.1 |
| 28 | 1596.0 | 1605.9 | 1615.9 | 1625.8 | 1635.8 | 1645.9 | 1655.9 | 1666.0 | 1676.2 | 1686.3 |
| 29 | 1696.5 | 1706.7 | 1717.0 | 1727.2 | 1737.5 | 1747.9 | 1758.2 | 1768.6 | 1779.1 | 1789.5 |

Base, 2*b* = 28 feet. Side slopes 1½ to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 2.8 | 5.7 | 8.5 | 11.4 | 14.4 | 17.3 | 20.3 | 23.4 | 26.4 |
| 1 | 29.5 | 32.6 | 35.8 | 38.9 | 42.1 | 45.4 | 48.6 | 51.9 | 55.3 | 58.6 |
| 2 | 62.0 | 65.4 | 68.9 | 72.3 | 75.8 | 79.4 | 82.9 | 86.5 | 90.2 | 93.8 |
| 3 | 97.5 | 101.2 | 105.0 | 108.7 | 112.5 | 116.4 | 120.2 | 124.1 | 128.1 | 132.0 |
| 4 | 136.0 | 140.0 | 144.1 | 148.1 | 152.2 | 156.4 | 160.5 | 164.7 | 169.0 | 173.2 |
| 5 | 177.5 | 181.8 | 186.2 | 190.5 | 194.9 | 199.4 | 203.8 | 208.3 | 212.9 | 217.4 |
| 6 | 222.0 | 226.6 | 231.3 | 235.9 | 240.6 | 245.4 | 250.1 | 254.9 | 259.8 | 264.6 |
| 7 | 269.5 | 274.4 | 279.4 | 284.3 | 289.3 | 294.4 | 299.4 | 304.5 | 309.7 | 314.8 |
| 8 | 320.0 | 325.2 | 330.5 | 335.7 | 341.0 | 346 4 | 351.7 | 357.1 | 362.6 | 368.0 |
| 9 | 373.5 | 379.0 | 384.6 | 390.1 | 395.7 | 401.4 | 407.0 | 412.7 | 418.5 | 424.2 |
| 10 | 430.0 | 435.8 | 441.7 | 447.5 | 453.4 | 459.4 | 465.3 | 471.3 | 477.4 | 483.4 |
| 11 | 489.5 | 495.6 | 501.8 | 507.9 | 514.1 | 520.4 | 526.6 | 532.9 | 539.3 | 545.6 |
| 12 | 552.0 | 558.4 | 564.9 | 571.3 | 577.8 | 584.4 | 590.9 | 597.5 | 604.2 | 610.8 |
| 13 | 617.5 | 624.2 | 631.0 | 637.7 | 644.5 | 651.4 | 658.2 | 665.1 | 672.1 | 679.0 |
| 14 | 686.0 | 693.0 | 700.1 | 707.1 | 714.2 | 721.4 | 728.5 | 735.7 | 743.0 | 750.2 |
| 15 | 757.5 | 764.8 | 772.2 | 779.5 | 786.9 | 794.4 | 801.8 | 809.3 | 816.9 | 824.4 |
| 16 | 832.0 | 839.6 | 847.3 | 854.9 | 862.6 | 870.4 | 878.1 | 885.9 | 893.8 | 901.6 |
| 17 | 909.5 | 917.4 | 925.4 | 933.3 | 941.3 | 949.4 | 957.4 | 965.5 | 973.7 | 981.8 |
| 18 | 990.0 | 998.2 | 1006.5 | 1014.7 | 1023.0 | 1031.4 | 1039.7 | 1048.1 | 1056.6 | 1065.0 |
| 19 | 1073.5 | 1082.0 | 1090.6 | 1099.1 | 1107.7 | 1116.4 | 1125.0 | 1133.7 | 1142.5 | 1151.2 |
| 20 | 1160.0 | 1168.8 | 1177.7 | 1186.5 | 1195.4 | 1204.4 | 1213.3 | 1222.3 | 1231.4 | 1240.4 |
| 21 | 1249.5 | 1258.6 | 1267.8 | 1276.9 | 1286.1 | 1295.4 | 1304.6 | 1313.9 | 1323.3 | 1332.6 |
| 22 | 1342.0 | 1351.4 | 1360.9 | 1370.3 | 1379.8 | 1389.4 | 1398.9 | 1408.5 | 1418.2 | 1427.8 |
| 23 | 1437.5 | 1447.2 | 1457.0 | 1466.7 | 1476.5 | 1486.4 | 1496.2 | 1506.1 | 1516.1 | 1526.0 |
| 24 | 1536.0 | 1546.0 | 1556.1 | 1566.1 | 1576.2 | 1586.4 | 1596.5 | 1606.7 | 1617.0 | 1627.2 |
| 25 | 1637.5 | 1647.8 | 1658.2 | 1668.5 | 1678.9 | 1689.4 | 1699.8 | 1710.3 | 1720.9 | 1731.4 |
| 26 | 1742.0 | 1752.6 | 1763.3 | 1773.9 | 1784.6 | 1795.4 | 1806.1 | 1816.9 | 1827.8 | 1838.6 |
| 27 | 1849.5 | 1860.4 | 1871.4 | 1882 3 | 1893.3 | 1904.4 | 1915.4 | 1926.5 | 1937.7 | 1948.8 |
| 28 | 1960.0 | 1971.2 | 1982.5 | 1993.7 | 2005.0 | 2016.4 | 2027.7 | 2039.1 | 2050.6 | 2062.0 |
| 29 | 2073.5 | 2085.0 | 2096.6 | 2108.1 | 2119.7 | 2131.4 | 2143.0 | 2154.7 | 2166.5 | 2178.2 |

Base, 2*b* = 18 feet. Side slopes 1 to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 1.8 | 3.6 | 5.5 | 7.4 | 9.3 | 11.2 | 13.1 | 15.0 | 17.0 |
| 1 | 19.0 | 21.0 | 23.0 | 25.1 | 27.2 | 29.3 | 31.4 | 33.5 | 35.6 | 37.8 |
| 2 | 40.0 | 42.2 | 44.4 | 46.7 | 49.0 | 51.3 | 53.6 | 55.9 | 58.2 | 60.6 |
| 3 | 63.0 | 65.4 | 67.8 | 70.3 | 72.8 | 75.3 | 77.8 | 80.3 | 82.8 | 85.4 |
| 4 | 88.0 | 90.6 | 93.2 | 95.9 | 98.6 | 101.3 | 104.0 | 106.7 | 109.4 | 112.2 |
| 5 | 115.0 | 117.8 | 120.6 | 123.5 | 126.4 | 129.3 | 132.2 | 135.1 | 138.0 | 141.0 |
| 6 | 144.0 | 147.0 | 150.0 | 153.1 | 156.2 | 159.3 | 162.4 | 165.5 | 168.6 | 171.8 |
| 7 | 175.0 | 178.2 | 181.4 | 184.7 | 188.0 | 191.3 | 194.6 | 197.9 | 201.2 | 204.6 |
| 8 | 208.0 | 211.4 | 214.8 | 218.3 | 221 8 | 225.3 | 228.8 | 232.3 | 235.8 | 239.4 |
| 9 | 243.0 | 246.6 | 250.2 | 253.9 | 257.6 | 261.3 | 265.0 | 268.7 | 272.4 | 276.2 |
| 10 | 280.0 | 283.8 | 287.6 | 291.5 | 295.4 | 299.3 | 303.2 | 307.1 | 311.0 | 315.0 |
| 11 | 319.0 | 323.0 | 327.0 | 331.1 | 335.2 | 339.3 | 343.4 | 347.5 | 351.6 | 355.8 |
| 12 | 360.0 | 364.2 | 368.4 | 372.7 | 377.0 | 381.3 | 385.6 | 389.9 | 394.2 | 398.6 |
| 13 | 403.0 | 407.4 | 411.8 | 416.3 | 420.8 | 425.3 | 429.8 | 434.3 | 438.8 | 443.4 |
| 14 | 448.0 | 452.6 | 457.2 | 461.9 | 466.6 | 471.3 | 476.0 | 480.7 | 485.4 | 490.2 |
| 15 | 495.0 | 499.8 | 504.6 | 509.5 | 514.4 | 519.3 | 524.2 | 529.1 | 534.0 | 539.0 |
| 16 | 544.0 | 549.0 | 554.0 | 559.1 | 564.2 | 569.3 | 574.4 | 579.5 | 584.6 | 589.8 |
| 17 | 595.0 | 600.2 | 605.4 | 610.7 | 616.0 | 621.3 | 626.6 | 631.9 | 637.2 | 642.6 |
| 18 | 648.0 | 653 4 | 658.8 | 664.3 | 669.8 | 675.3 | 680.8 | 686.3 | 691.8 | 697.4 |
| 19 | 703.0 | 708.6 | 714.2 | 719.9 | 725.6 | 731.3 | 737.0 | 742.7 | 748.4 | 754.2 |
| 20 | 760.0 | 765.8 | 771.6 | 777.5 | 783.4 | 789.3 | 795.2 | 801.1 | 807.0 | 813.0 |
| 21 | 819.0 | 825.0 | 831.0 | 837.1 | 843.2 | 849.3 | 855.4 | 861.5 | 867.6 | 873.8 |
| 22 | 880.0 | 886.2 | 892.4 | 898.7 | 905.0 | 911.3 | 917.6 | 923.9 | 930.2 | 936.6 |
| 23 | 943.0 | 949.4 | 955.8 | 962.3 | 968.8 | 975.3 | 981.8 | 988.3 | 994.8 | 1001.4 |
| 24 | 1008.0 | 1014.6 | 1021.2 | 1027.9 | 1034.6 | 1041.3 | 1048.0 | 1054.7 | 1061.4 | 1068.2 |
| 25 | 1075 0 | 1081.8 | 1088.6 | 1095.5 | 1102.4 | 1109.3 | 1116.2 | 1123.1 | 1130 0 | 1137.0 |
| 26 | 1144.0 | 1151.0 | 1158.0 | 1165 1 | 1172.2 | 1179 3 | 1186.4 | 1193.5 | 1200.6 | 1207.8 |
| 27 | 1215.0 | 1222.2 | 1229.4 | 1236.7 | 1244.0 | 1251.3 | 1258.6 | 1265.9 | 1273.2 | 1280.6 |
| 28 | 1288.0 | 1295 4 | 1302.8 | 1310.3 | 1317.8 | 1325.3 | 1332.8 | 1340.3 | 1347.8 | 1355.4 |
| 29 | 1363.0 | 1370.6 | 1378.2 | 1385.9 | 1393.6 | 1401.3 | 1409.0 | 1416.7 | 1424.4 | 1432.2 |

Base, $2b$ = 20 feet. Side slopes 1 to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 2.0 | 4.0 | 6.1 | 8.2 | 10.3 | 12.4 | 14.5 | 16.6 | 18.8 |
| 1 | 21.0 | 23.2 | 25.4 | 27.7 | 30.0 | 32.3 | 34.6 | 36.9 | 39.2 | 41.6 |
| 2 | 44.0 | 46.4 | 48.8 | 51.3 | 53.8 | 56.3 | 58.8 | 61.3 | 63.8 | 66.4 |
| 3 | 69.0 | 71.6 | 74.2 | 76.9 | 79.6 | 82.3 | 85.0 | 87.7 | 90.4 | 93.2 |
| 4 | 96.0 | 98.8 | 101.6 | 104.5 | 107.4 | 110.3 | 113.2 | 116.1 | 119.0 | 122.0 |
| 5 | 125.0 | 128.0 | 131.0 | 134.1 | 137.2 | 140.3 | 143.4 | 146.5 | 149.6 | 152.8 |
| 6 | 156.0 | 159.2 | 162.4 | 165.7 | 169.0 | 172.3 | 175.6 | 178.9 | 182.2 | 185.6 |
| 7 | 189.0 | 192.4 | 195.8 | 199.3 | 202.8 | 206.3 | 209.8 | 213.3 | 216.8 | 220.4 |
| 8 | 224.0 | 227.6 | 231.2 | 234.9 | 238.6 | 242.3 | 246.0 | 249.7 | 253.4 | 257.2 |
| 9 | 261.0 | 264.8 | 268.6 | 272.5 | 276.4 | 280.3 | 284.2 | 288.1 | 292.0 | 296.0 |
| 10 | 300.0 | 304.0 | 308.0 | 312.1 | 316.2 | 320.3 | 324.4 | 328.5 | 332.6 | 336.8 |
| 11 | 341.0 | 345.2 | 349.4 | 353.7 | 358.0 | 362.3 | 366.6 | 370.9 | 375.2 | 379.6 |
| 12 | 384.0 | 388.4 | 392.8 | 397.3 | 401.8 | 406.3 | 410.8 | 415.3 | 419.8 | 424.4 |
| 13 | 429.0 | 433.6 | 438.2 | 442.9 | 447.6 | 452.3 | 457.0 | 461.7 | 466.4 | 471.2 |
| 14 | 476.0 | 480.8 | 485.6 | 490.5 | 495.4 | 500.3 | 505.2 | 510.1 | 515.0 | 520.0 |
| 15 | 525.0 | 530.0 | 535.0 | 540.1 | 545.2 | 550.3 | 555.4 | 560.5 | 565.6 | 570.8 |
| 16 | 576.0 | 581.2 | 586.4 | 591.7 | 597.0 | 602.3 | 607.6 | 612.9 | 618.2 | 623.6 |
| 17 | 629.0 | 634.4 | 639.8 | 645.3 | 650.8 | 656.3 | 661.8 | 667.3 | 672.8 | 678.4 |
| 18 | 684.0 | 689.6 | 695.2 | 700.9 | 706.6 | 712.3 | 718.0 | 723.7 | 729.4 | 735.2 |
| 19 | 741.0 | 746.8 | 752.6 | 758.5 | 764.4 | 770.3 | 776.2 | 782.1 | 788.0 | 794.0 |
| 20 | 800.0 | 806.0 | 812.0 | 818.1 | 824.2 | 830.3 | 836.4 | 842.5 | 848.6 | 854.8 |
| 21 | 861.0 | 867.2 | 873.4 | 879.7 | 886.0 | 892.3 | 898.6 | 904.9 | 911.2 | 917.6 |
| 22 | 924.0 | 930.4 | 936.8 | 943.3 | 949.8 | 956.3 | 962.8 | 969.3 | 975.8 | 982.4 |
| 23 | 989.0 | 995.6 | 1002.2 | 1008.9 | 1015.6 | 1022.3 | 1029.0 | 1035.7 | 1042.4 | 1049.2 |
| 24 | 1056.0 | 1062.8 | 1069.6 | 1076.5 | 1083.4 | 1090.3 | 1097.2 | 1104.1 | 1111.0 | 1118.0 |
| 25 | 1125.0 | 1132.0 | 1139.0 | 1146.1 | 1153.2 | 1160.3 | 1167.4 | 1174.5 | 1181.6 | 1188.8 |
| 27 | 1196.0 | 1203.2 | 1210.4 | 1217.7 | 1225.0 | 1232.3 | 1239.6 | 1246.9 | 1254.2 | 1261.6 |
| 26 | 1269.0 | 1276.4 | 1283.8 | 1291.3 | 1298.8 | 1306.3 | 1313.8 | 1321.3 | 1328.8 | 1336.4 |
| 28 | 1344.0 | 1351.6 | 1359.2 | 1366.9 | 1374.6 | 1382.3 | 1390.0 | 1397.7 | 1405.4 | 1413.2 |
| 29 | 1421.0 | 1428.8 | 1436.6 | 1444.5 | 1452.4 | 1460.3 | 1468.2 | 1476.1 | 1484.0 | 1492.0 |

Base, $2b$ = 30 feet. Side slopes 1 to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 3.0 | 6.0 | 9.1 | 12.2 | 15.3 | 18.4 | 21.5 | 24.6 | 27.8 |
| 1 | 31.0 | 34.2 | 37.4 | 40.7 | 44.0 | 47.3 | 50.6 | 53.9 | 57.2 | 60.6 |
| 2 | 64.0 | 67.4 | 70.8 | 74.3 | 77.8 | 81.3 | 84.8 | 88.3 | 91.8 | 95.4 |
| 3 | 99.0 | 102.6 | 106.2 | 109.9 | 113.6 | 117.3 | 121.0 | 124.7 | 128.4 | 132.2 |
| 4 | 136.0 | 139.8 | 143.6 | 147.5 | 151.4 | 155.3 | 159.2 | 163.1 | 167.0 | 171.0 |
| 5 | 175.0 | 179.0 | 183.0 | 187.1 | 191.2 | 195.3 | 199.4 | 203.5 | 207.6 | 211.8 |
| 6 | 216.0 | 220.2 | 224.4 | 228.7 | 233.0 | 237.3 | 241.6 | 245.9 | 250.2 | 254.6 |
| 7 | 259.0 | 263.4 | 267.8 | 272.3 | 276.8 | 281.3 | 285.8 | 290.3 | 294.8 | 299.4 |
| 8 | 304.0 | 308.6 | 313.2 | 317.9 | 322.6 | 327.3 | 332.0 | 336.7 | 341.4 | 346.2 |
| 9 | 351.0 | 355.8 | 360.6 | 365.5 | 370.4 | 375.3 | 380.2 | 385.1 | 390.0 | 395.0 |
| 10 | 400.0 | 405.0 | 410.0 | 415.1 | 420.2 | 425.3 | 430.4 | 435.5 | 440.6 | 445.8 |
| 11 | 451.0 | 456.2 | 461.4 | 466.7 | 472.0 | 477.3 | 482.6 | 487.9 | 493.2 | 498.6 |
| 12 | 504.0 | 509.4 | 514.8 | 520.3 | 525.8 | 531.3 | 536.8 | 542.3 | 547.8 | 553.4 |
| 13 | 559.0 | 564.6 | 570.2 | 575.9 | 581.6 | 587.3 | 593.0 | 598.7 | 604.4 | 610.2 |
| 14 | 616.0 | 621.8 | 627.6 | 633.5 | 639.4 | 645.3 | 651.2 | 657.1 | 663.0 | 669.0 |
| 15 | 675.0 | 681.0 | 687.0 | 693.1 | 699.2 | 705.3 | 711.4 | 717.5 | 723.6 | 729.8 |
| 16 | 736.0 | 742.2 | 748.4 | 754.7 | 761.0 | 767.3 | 773.6 | 779.9 | 786.2 | 792.6 |
| 17 | 799.0 | 805.4 | 811.8 | 818.3 | 824.8 | 831.3 | 837.8 | 844.3 | 850.8 | 857.4 |
| 18 | 864.0 | 870.6 | 877.2 | 883.9 | 890.6 | 897.3 | 904.0 | 910.7 | 917.4 | 924.2 |
| 19 | 931.0 | 937.8 | 944.6 | 951.5 | 958.4 | 965.3 | 972.2 | 979.1 | 986.0 | 993.0 |
| 20 | 1000.0 | 1007.0 | 1014.0 | 1021.1 | 1028.2 | 1035.3 | 1042.4 | 1049.5 | 1056.6 | 1063.8 |
| 21 | 1071.0 | 1078.2 | 1085.4 | 1092.7 | 1100.0 | 1107.3 | 1114.6 | 1121.9 | 1129.2 | 1136.6 |
| 22 | 1144.0 | 1151.4 | 1158.8 | 1166.3 | 1173.8 | 1181.3 | 1188.8 | 1196.3 | 1203.8 | 1211.4 |
| 23 | 1219.0 | 1226.6 | 1234.2 | 1241.9 | 1249.6 | 1257.3 | 1265.0 | 1272.7 | 1280.4 | 1288.2 |
| 24 | 1296.0 | 1303.8 | 1311.6 | 1319.5 | 1327.4 | 1335.3 | 1343.2 | 1351.1 | 1359.0 | 1367.0 |
| 25 | 1375.0 | 1383.0 | 1391.0 | 1399.1 | 1407.2 | 1415.3 | 1423.4 | 1431.5 | 1439.6 | 1447.8 |
| 26 | 1456.0 | 1464.2 | 1472.4 | 1480.7 | 1489.0 | 1497.3 | 1505.6 | 1513.9 | 1522.2 | 1530.6 |
| 27 | 1539.0 | 1517.4 | 1555.8 | 1564.3 | 1572.8 | 1581.3 | 1589.8 | 1598.3 | 1606.8 | 1615.4 |
| 28 | 1624.0 | 1632.6 | 1641.2 | 1619.9 | 1658.6 | 1667.3 | 1676.0 | 1684.7 | 1693.4 | 1702.2 |
| 29 | 1711.0 | 1719.8 | 1728.6 | 1737.5 | 1746.4 | 1755.3 | 1764.2 | 1773.1 | 1782.0 | 1791.0 |

Base, 2*b* = 16 feet. Side slopes ½ to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 1.6 | 3.2 | 4.8 | 6.4 | 8.1 | 9.7 | 11.3 | 13.0 | 14.6 |
| 1 | 16.3 | 17.9 | 19.6 | 21.2 | 22.9 | 24.6 | 26.2 | 27.9 | 29.6 | 31.3 |
| 2 | 33.0 | 34.7 | 36.4 | 38.1 | 39.8 | 41.6 | 43.3 | 45.0 | 46.8 | 48.5 |
| 3 | 50.3 | 52.0 | 53.8 | 55.5 | 57.3 | 59.1 | 60.8 | 62.6 | 64.4 | 66.2 |
| 4 | 68.0 | 69.8 | 71.6 | 73.4 | 75.2 | 77.1 | 78.9 | 80.7 | 82.6 | 84.4 |
| 5 | 86.3 | 88.1 | 90.0 | 91.8 | 93.7 | 95.6 | 97.4 | 99.3 | 101.2 | 103.1 |
| 6 | 105.0 | 106.9 | 108.8 | 110.7 | 112.6 | 114.6 | 116.5 | 118.4 | 120.4 | 122.3 |
| 7 | 124.3 | 126.2 | 128.2 | 130.1 | 132.1 | 134.1 | 136.0 | 138.0 | 140.0 | 142.0 |
| 8 | 144.0 | 146.0 | 148.0 | 150.0 | 152.0 | 154.1 | 156.1 | 158.1 | 160.2 | 162.2 |
| 9 | 164.3 | 166.3 | 168.4 | 170.4 | 172.5 | 174.6 | 176.6 | 178.7 | 180.8 | 182.9 |
| 10 | 185.0 | 187.1 | 189.2 | 191.3 | 193.4 | 195.6 | 197.7 | 199.8 | 202.0 | 204.1 |
| 11 | 206.3 | 208.4 | 210.6 | 212.7 | 214.9 | 217.1 | 219.2 | 221.4 | 223.6 | 225.8 |
| 12 | 228.0 | 230.2 | 232.4 | 234.6 | 236.8 | 239.1 | 241.3 | 243.5 | 245.8 | 248.0 |
| 13 | 250.3 | 252.5 | 254.8 | 257.0 | 259.3 | 261.6 | 263.8 | 266.1 | 268.4 | 270.7 |
| 14 | 273.0 | 275.3 | 277.6 | 279.9 | 282.2 | 284.6 | 286.9 | 289.2 | 291.6 | 293.9 |
| 15 | 296.3 | 298.6 | 301.0 | 303.3 | 305.7 | 308.1 | 310.4 | 312.8 | 315.2 | 317.6 |
| 16 | 320.0 | 322.4 | 324.8 | 327.2 | 329.6 | 332.1 | 334.5 | 336.9 | 339.4 | 341.8 |
| 17 | 344.3 | 346.7 | 349.2 | 351.6 | 354.1 | 356.6 | 359.0 | 361.5 | 364.0 | 366.5 |
| 18 | 369.0 | 371.5 | 374.0 | 376.5 | 379.0 | 381.6 | 384.1 | 386.6 | 389.2 | 391.7 |
| 19 | 394.3 | 396.8 | 399.4 | 401.9 | 404.5 | 407.1 | 409.6 | 412.2 | 414.8 | 417.4 |
| 20 | 420.0 | 422.6 | 425.2 | 427.8 | 430.4 | 433.1 | 435.7 | 438.3 | 441.0 | 443.6 |
| 21 | 446.3 | 448.9 | 451.6 | 454.2 | 456.9 | 459.6 | 462.2 | 464.9 | 467.6 | 470.3 |
| 22 | 473.0 | 475.7 | 478.4 | 481.1 | 483.8 | 486.6 | 489.3 | 492.0 | 494.8 | 497.5 |
| 23 | 500.3 | 503.0 | 505.8 | 508.5 | 511.3 | 514.1 | 516.8 | 519.6 | 522.4 | 525.2 |
| 24 | 528.0 | 530.8 | 533.6 | 536.4 | 539.2 | 542.1 | 544.9 | 547.7 | 550.6 | 553.4 |
| 25 | 556.3 | 559.1 | 562.0 | 564.8 | 567.7 | 570.6 | 573.4 | 576.3 | 579.2 | 582.1 |
| 26 | 585.0 | 587.9 | 590.8 | 593.7 | 596.6 | 599.6 | 602.5 | 605.4 | 608.4 | 611.3 |
| 27 | 614.3 | 617.2 | 620.2 | 623.1 | 626.1 | 629.1 | 632.0 | 635.0 | 638.0 | 641.0 |
| 28 | 644.0 | 647.0 | 650.0 | 653.0 | 656.0 | 659.1 | 662.1 | 665.1 | 668.2 | 671.2 |
| 29 | 674.3 | 677.3 | 680.4 | 683.4 | 686.5 | 689.6 | 692.6 | 695.7 | 698.8 | 701.9 |

Base, 2*b* = 18 feet. Side slopes ½ to 1.

| C. H. | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 1.8 | 3.6 | 5.4 | 7.2 | 9.1 | 10.9 | 12.7 | 14.6 | 16.4 |
| 1 | 18.3 | 20.1 | 22.0 | 23.8 | 25.7 | 27.6 | 29.4 | 31.3 | 33.2 | 35.1 |
| 2 | 37.0 | 38.9 | 40.8 | 42.7 | 44.6 | 46.6 | 48.5 | 50.4 | 52.4 | 54.3 |
| 3 | 56.3 | 58.2 | 60.2 | 62.1 | 64.1 | 66.1 | 68.0 | 70.0 | .0 | 74.0 |
| 4 | 76.0 | 78.0 | 80.0 | 82.0 | 84.0 | 86.1 | 88.1 | 90.1 | .2 | 94.2 |
| 5 | 96.3 | 98.3 | 100.4 | 102.4 | 104.5 | 106.6 | 108.6 | 110.7 | 112.8 | 114.9 |
| 6 | 117.0 | 119.1 | 121.2 | 123.3 | 125.4 | 127.6 | 129.7 | 131.8 | 134.0 | 136.1 |
| 7 | 138.3 | 140.4 | 142.6 | 144.7 | 146.9 | 149.1 | 151.2 | 153.4 | 155.6 | 157.8 |
| 8 | 160.0 | 162.2 | 164.4 | 166.6 | 168.8 | 171.1 | 173.3 | 175.5 | 177.8 | 180.0 |
| 9 | 182.3 | 184.5 | 186.8 | 189.0 | 191.3 | 193.6 | 195.8 | 198.1 | 200.4 | 202.7 |
| 10 | 205.0 | 207.3 | 209.6 | 211.9 | 214.2 | 216.6 | 218.9 | 221.2 | 223.6 | 225.9 |
| 11 | 228.3 | 230.6 | 233.0 | 235.3 | 237.7 | 240.1 | 242.4 | 244.8 | 247.2 | 249.6 |
| 12 | 252.0 | 254.4 | 256.8 | 259.2 | 261.6 | 264.1 | 266.5 | 268.9 | 271.4 | 273.8 |
| 13 | 276.3 | 278.7 | 281.2 | 283.6 | 286.1 | 288.6 | 291.0 | 293.5 | 296.0 | 298.5 |
| 14 | 301.0 | 303.5 | 306.0 | 308.5 | 311.0 | 313.6 | 316.1 | 318.6 | 321.2 | 323.7 |
| 15 | 326.3 | 328.8 | 331.4 | 333.9 | 336.5 | 339.1 | 341.6 | 344.2 | 346 8 | 349.4 |
| 16 | 352.0 | 354.6 | 357.2 | 359.8 | 362.4 | 365.1 | 367.7 | 370.3 | 373.0 | 375.6 |
| 17 | 378.3 | 380.9 | 383.6 | 386.2 | 388.9 | 391.6 | 394.2 | 396.9 | 399.6 | 402.3 |
| 18 | 405.0 | 407.7 | 410.4 | 413.1 | 415.8 | 418.6 | 421.3 | 424 0 | 426.8 | 429.5 |
| 19 | 432.3 | 435.0 | 437.8 | 440.5 | 443.3 | 446.1 | 448.8 | 451.6 | 454.4 | 457.2 |
| 20 | 460.0 | 462.8 | 465.6 | 468.4 | 471.2 | 474.1 | 476.9 | 479.7 | 482.6 | 485.4 |
| 21 | 488.3 | 491.1 | 494.0 | 496.8 | 499.7 | 502.6 | 505.4 | 508.3 | 511.2 | 514.1 |
| 22 | 517.0 | 519.9 | 522.8 | 525.7 | 528.6 | 531.6 | 534.5 | 537.4 | 540.4 | 543.3 |
| 23 | 546.3 | 549.2 | 552.2 | 555.1 | 558.1 | 561.1 | 564.0 | 567.0 | 570.0 | 573.0 |
| 24 | 576.0 | 579.0 | 582.0 | 585.0 | 588.0 | 591.1 | 594.1 | 597.1 | 600.2 | 603.2 |
| 25 | 606.3 | 609.3 | 612.4 | 615.4 | 618.5 | 621.6 | 624.6 | 627.7 | 630.8 | 633.9 |
| 26 | 637.0 | 640.1 | 643.2 | 646.3 | 649.4 | 652.6 | 655.7 | 658.8 | 662.0 | 665.1 |
| 27 | 668.3 | 671.4 | 674.6 | 677.7 | 680.9 | 684.1 | 687.2 | 690.4 | 693.6 | 696.8 |
| 28 | 700.0 | 703.2 | 706.4 | 709.6 | 712.8 | 716.1 | 719.3 | 722.5 | 725.8 | 729.0 |
| 29 | 732.3 | 735.5 | 738.8 | 742.0 | 745.3 | 748.6 | 751.8 | 755.1 | 758.4 | 761.7 |

## XVIII.—AREA CORRECTIONS FOR 3-LEVEL GROUND.

**Correction $(h_m - h_0)^2 s$. (See 221.)**

SIDE SLOPES 1½ TO 1.

| $h_m - h_0$ | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.4 | 0.5 | 0.7 | 1.0 | 1.2 |
| 1 | 1.5 | 1.8 | 2.2 | 2.5 | 2.9 | 3.4 | 3.8 | 4.3 | 4.9 | 5.4 |
| 2 | 6.0 | 6.6 | 7.3 | 7.9 | 8.6 | 9.4 | 10.1 | 10.9 | 11.8 | 12.6 |
| 3 | 13.5 | 14.4 | 15.4 | 16.3 | 17.3 | 18.4 | 19.4 | 20.5 | 21.7 | 22.8 |
| 4 | 24.0 | 25.2 | 26.5 | 27.7 | 29.0 | 30.4 | 31.7 | 33.1 | 34.6 | 36.0 |
| 5 | 37.5 | 39.0 | 40.6 | 42.1 | 43.7 | 45.4 | 47.0 | 48.7 | 50.5 | 52.2 |
| 6 | 54.0 | 55.8 | 57.7 | 59.5 | 61.4 | 63.4 | 65.3 | 67.3 | 69.4 | 71.4 |
| 7 | 73.5 | 75.6 | 77.8 | 79.9 | 82.1 | 84.4 | 86.6 | 88.9 | 91.3 | 93.6 |
| 8 | 96.0 | 98.4 | 100.9 | 103.3 | 105.8 | 108.4 | 110.9 | 113.5 | 116.2 | 118.8 |
| 9 | 121.5 | 124.2 | 127.0 | 129.7 | 132.5 | 135.4 | 138.2 | 141.1 | 144.1 | 147.0 |
| 10 | 150.0 | 153.0 | 156.1 | 159.1 | 162.2 | 165.4 | 168.5 | 171.7 | 175.0 | 178.2 |
| 11 | 181.5 | 184.8 | 188.2 | 191.5 | 194.9 | 198.4 | 201.8 | 205.3 | 208.9 | 212.4 |

SIDE SLOPES 1 TO 1.

| $h_m - h_0$ | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 |
| 1 | 1.0 | 1.2 | 1.4 | 1.7 | 2.0 | 2.3 | 2.6 | 2.9 | 3.2 | 3.6 |
| 2 | 4.0 | 4.4 | 4.8 | 5.3 | 5.8 | 6.3 | 6.8 | 7.3 | 7.8 | 8.4 |
| 3 | 9.0 | 9.6 | 10.2 | 10.9 | 11.6 | 12.3 | 13.0 | 13.7 | 14.4 | 15.2 |
| 4 | 16.0 | 16.8 | 17.6 | 18.5 | 19.4 | 20.3 | 21.2 | 22.1 | 23.0 | 24.0 |
| 5 | 25.0 | 26.0 | 27.0 | 28.1 | 29.2 | 30.3 | 31.4 | 32.5 | 33.6 | 34.8 |
| 6 | 36.0 | 37.2 | 38.4 | 39.7 | 41.0 | 42.3 | 43.6 | 44.9 | 46.2 | 47.6 |
| 7 | 49.0 | 50.4 | 51.8 | 53.3 | 54.8 | 56.3 | 57.8 | 59.3 | 60.8 | 62.4 |
| 8 | 64.0 | 65.6 | 67.2 | 68.9 | 70.6 | 72.3 | 74.0 | 75.7 | 77.4 | 79.2 |
| 9 | 81.0 | 82.8 | 84.6 | 86.5 | 88.4 | 90.3 | 92.2 | 94.1 | 96.0 | 98.0 |
| 10 | 100.0 | 102.0 | 104.0 | 106.1 | 108.2 | 110.3 | 112.4 | 114.5 | 116.6 | 118.8 |
| 11 | 121.0 | 123.2 | 125.4 | 127.7 | 130.0 | 132.3 | 134.6 | 136.9 | 139.2 | 141.6 |

SIDE SLOPES ½ TO 1.

| $h_m - h_0$ | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 |
| 1 | 0.5 | 0.6 | 0.7 | 0.8 | 1.0 | 1.1 | 1.3 | 1.4 | 1.6 | 1.8 |
| 2 | 2.0 | 2.2 | 2.4 | 2.6 | 2.9 | 3.1 | 3.4 | 3.6 | 3.9 | 4.2 |
| 3 | 4.5 | 4.8 | 5.1 | 5.4 | 5.8 | 6.1 | 6.5 | 6.8 | 7.2 | 7.6 |
| 4 | 8.0 | 8.4 | 8.8 | 9.2 | 9.7 | 10.1 | 10.6 | 11.0 | 11.5 | 12.0 |
| 5 | 12.5 | 13.0 | 13.5 | 14.0 | 14 6 | 15.1 | 15.7 | 16.2 | 16.8 | 17.4 |
| 6 | 18.0 | 18.6 | 19.2 | 19.8 | 20.5 | 21.1 | 21.8 | 22.4 | 23.1 | 23.8 |
| 7 | 24.5 | 25.2 | 25.9 | 26.6 | 27.4 | 28.1 | 28.9 | 29.6 | 30.4 | 31.2 |
| 8 | 32.0 | 32.8 | 33.6 | 34.4 | 35.3 | 36.1 | 37.0 | 37.8 | 38.7 | 39.6 |
| 9 | 40.5 | 41.4 | 42.3 | 43.2 | 44.2 | 45.1 | 46.1 | 47.0 | 48.0 | 49.0 |
| 10 | 50.0 | 51.0 | 52.0 | 53.0 | 54.1 | 55.1 | 56.2 | 57.2 | 58.3 | 59.4 |
| 11 | 60.5 | 61.6 | 62.7 | 63.8 | 65.0 | 66.1 | 67.3 | 68.4 | 69.6 | 70.8 |

SIDE SLOPES ¼ TO 1.

| $h_m - h_0$ | .0 | .1 | .2 | .3 | .4 | .5 | .6 | .7 | .8 | .9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| 1 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 | 0.9 |
| 2 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.6 | 1.7 | 1.8 | 2.0 | 2.1 |
| 3 | 2.3 | 2.4 | 2.6 | 2.7 | 2.9 | 3.1 | 3.2 | 3.4 | 3.6 | 3.8 |
| 4 | 4.0 | 4.2 | 4.4 | 4.6 | 4.8 | 5.1 | 5.3 | 5.5 | 5.8 | 6.0 |
| 5 | 6 3 | 6.5 | 6.8 | 7.0 | 7.3 | 7.6 | 7.8 | 8.1 | 8.4 | 8.7 |
| 6 | 9.0 | 9 3 | 9.6 | 9.9 | 10.2 | 10.6 | 10.9 | 11.2 | 11.6 | 11.9 |
| 7 | 12.3 | 12.6 | 13.0 | 13.3 | 13.7 | 14.1 | 14.4 | 14.8 | 15.2 | 15.6 |
| 8 | 16.0 | 16.4 | 16.8 | 17.2 | 17.6 | 18.1 | 18.5 | 18.9 | 19.4 | 19.8 |
| 9 | 20.3 | 20.7 | 21.2 | 21.6 | 22.1 | 22.6 | 23.0 | 23.5 | 24.0 | 24.5 |
| 10 | 25.0 | 25.5 | 26.0 | 26.5 | 27.0 | 27.6 | 28.1 | 28.6 | 29.2 | 29.7 |
| 11 | 30.3 | 30.8 | 21.4 | 31.9 | 32.5 | 33.1 | 33.6 | 34.2 | 34.8 | 35.4 |

| Ht. in Ft. | Width of base ($=2b$) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 0.1 | 5.2 | 5.9 | 6.7 | 7.4 | 8.2 | 8.9 | 9.6 | 10.4 | 11.1 | 11.9 |
| .2 | 10.4 | 11.9 | 13.4 | 14.9 | 16.3 | 17.8 | 19.3 | 20.8 | 22.3 | 23.7 |
| .3 | 15.6 | 17.9 | 20.1 | 22.3 | 24.5 | 26.8 | 29.0 | 31.2 | 33.4 | 35.6 |
| .4 | 20.9 | 23.9 | 26.8 | 29.8 | 32.7 | 35.7 | 38.7 | 41.6 | 44.6 | 47.5 |
| .5 | 26.2 | 29.9 | 33.6 | 37.3 | 41.0 | 44.7 | 48.4 | 52.1 | 55.8 | 59.5 |
| .6 | 31.4 | 35.9 | 40.3 | 44.8 | 49.2 | 53.7 | 58.1 | 62.6 | 67.0 | 71.4 |
| .7 | 36.7 | 41.9 | 47.1 | 52.3 | 57.5 | 62.7 | 67.9 | 73.1 | 78.3 | 83.4 |
| .8 | 42.1 | 48.0 | 53.9 | 59.9 | 65.8 | 71.7 | 77.6 | 83.6 | 89.5 | 95.4 |
| .9 | 47.8 | 54.1 | 60.8 | 67.4 | 74.1 | 80.8 | 87.4 | 94.1 | 100.8 | 107.4 |
| 1.0 | 52.8 | 60.2 | 67.6 | 75.0 | 82.4 | 89.8 | 97.2 | 104.6 | 112.0 | 119.4 |
| 1.1 | 58.2 | 66.3 | 74.5 | 82.6 | 90.8 | 98.9 | 107.1 | 115.2 | 123.3 | 131.5 |
| .2 | 63.6 | 72.4 | 81.3 | 90.2 | 99.1 | 108.0 | 116.9 | 125.8 | 134.7 | 143.6 |
| .3 | 69.0 | 78.6 | 88.2 | 97.9 | 107.5 | 117.1 | 126.8 | 136.4 | 146.0 | 155.6 |
| .4 | 74.4 | 84.8 | 95.1 | 105.5 | 115.9 | 126.3 | 136.6 | 147.0 | 157.4 | 167.7 |
| .5 | 79.9 | 91.0 | 102.1 | 113.2 | 124.3 | 135.4 | 146.5 | 157.6 | 168.8 | 179.9 |
| .6 | 85.3 | 97.2 | 109.0 | 120.9 | 132.7 | 144.6 | 156.4 | 168.3 | 180.1 | 192.0 |
| .7 | 90.8 | 103.4 | 116.0 | 128.6 | 141.2 | 153.8 | 166.4 | 179.0 | 191.6 | 204.1 |
| .8 | 96.3 | 109.7 | 123.0 | 136.3 | 149.7 | 163.0 | 176.3 | 189.7 | 203.0 | 216.3 |
| .9 | 101.9 | 115.9 | 130.0 | 144.1 | 157.3 | 172.2 | 186.3 | 200.4 | 214.4 | 228.5 |
| 2.0 | 107.4 | 122.2 | 137.0 | 151.9 | 166.7 | 181.5 | 196.3 | 211.1 | 225.9 | 240.7 |
| 2.1 | 113.0 | 128.5 | 144.1 | 159.6 | 175.2 | 190.8 | 206.3 | 221.9 | 237.4 | 253.0 |
| .2 | 118.6 | 134.9 | 151.1 | 167.4 | 183.7 | 200.0 | 216.3 | 232.6 | 248.9 | 256.2 |
| .3 | 124.2 | 141.2 | 158.2 | 175.3 | 192.3 | 209.3 | 226.4 | 243.4 | 260.4 | 277.5 |
| .4 | 129.8 | 147.6 | 165.3 | 183.1 | 200.9 | 218.7 | 236.4 | 254.2 | 272.0 | 289.7 |
| .5 | 135.4 | 153.9 | 172.5 | 191.0 | 209.5 | 228.0 | 246.5 | 265.0 | 283.5 | 302.0 |
| .6 | 141.1 | 160.3 | 179.6 | 198.9 | 218.1 | 230.0 | 256.6 | 275.9 | 295.1 | 314.4 |
| .7 | 146.7 | 166.7 | 186.8 | 206.8 | 226.8 | 246.8 | 266.8 | 286.8 | 306.8 | 326.8 |
| .8 | 152.4 | 173.1 | 193.9 | 214.7 | 235.4 | 256.2 | 276.9 | 297.6 | 318.4 | 339.1 |
| .9 | 158.2 | 179.6 | 201.1 | 222.6 | 244.1 | 265.6 | 287.0 | 308.5 | 330.0 | 351.5 |
| 3.0 | 163.9 | 186.1 | 208.3 | 230.6 | 252.8 | 275.0 | 297.2 | 319.4 | 341.7 | 363.9 |
| 3.1 | 169.6 | 192.6 | 215.6 | 238.5 | 261.5 | 284.4 | 307.4 | 330.4 | 353.3 | 376.3 |
| .2 | 175.4 | 199.1 | 222.8 | 246.5 | 270.2 | 293.9 | 317.6 | 341.3 | 365.0 | 388.7 |
| .3 | 181.2 | 205.6 | 230.1 | 254.5 | 279.0 | 303.4 | 327.9 | 351.9 | 376.3 | 400.8 |
| .4 | 187.0 | 212.2 | 237.4 | 262.6 | 287.7 | 312.9 | 338.1 | 363.3 | 388.5 | 413.6 |
| .5 | 192.8 | 218.7 | 244.7 | 270.6 | 296.5 | 322.4 | 348.4 | 374.3 | 400.2 | 426.1 |
| .6 | 198.7 | 225.3 | 252.0 | 278.7 | 305.3 | 332.0 | 358.7 | 385.3 | 412.0 | 438.6 |
| .7 | 204.5 | 231.9 | 259.3 | 286.8 | 314.1 | 341.6 | 369.0 | 396.4 | 423.8 | 451.2 |
| .8 | 210.4 | 238.5 | 266.7 | 294.9 | 322.3 | 350.4 | 378.6 | 406.7 | 434.9 | 463.0 |
| .9 | 216.3 | 245.2 | 274.1 | 303.0 | 331.8 | 360.7 | 389.6 | 418.5 | 447.4 | 476.3 |
| 4.0 | 222.2 | 251.9 | 281.5 | 311.1 | 340.7 | 370.4 | 400.0 | 429.6 | 459.2 | 488.8 |
| 4.1 | 228.2 | 258.5 | 288.9 | 319.3 | 349.7 | 380.1 | 410.4 | 440.8 | 471.1 | 501.5 |
| .2 | 234.1 | 265.2 | 296.3 | 327.4 | 358.5 | 389.6 | 420.7 | 451.8 | 482.9 | 514.0 |
| .3 | 240.1 | 272.0 | 303.8 | 335.6 | 367.5 | 399.3 | 431.2 | 463.0 | 494.9 | 526.7 |
| .4 | 246.1 | 278.7 | 311.3 | 343.9 | 376.4 | 409.0 | 441.6 | 474.2 | 506.8 | 539.4 |
| .5 | 252.1 | 285.4 | 318.8 | 352.1 | 385.4 | 418.7 | 452.1 | 485.4 | 518.7 | 552.1 |
| .6 | 258.1 | 292.2 | 326.3 | 360.3 | 394.4 | 428.5 | 462.5 | 496.6 | 530.7 | 564.8 |
| .7 | 264.2 | 299.0 | 333.8 | 368.6 | 403.4 | 438.2 | 473.0 | 507.8 | 542.6 | 577.5 |
| .8 | 270.2 | 305.8 | 341.3 | 376.9 | 412.4 | 448.0 | 483.5 | 519.1 | 554.6 | 590.2 |
| .9 | 276.3 | 312.6 | 348.9 | 385.2 | 421.5 | 457.8 | 494.1 | 530.3 | 566.6 | 602.9 |
| 5.0 | 282.4 | 319.4 | 356.5 | 393.5 | 430.6 | 467.6 | 504.6 | 541.7 | 578.7 | 615.7 |
| 5.1 | 288.5 | 326.3 | 364.1 | 401.9 | 439.6 | 477.4 | 515.2 | 553.0 | 590.7 | 628.5 |
| .2 | 294.7 | 333.2 | 371.7 | 410.2 | 448.7 | 487.3 | 525.8 | 564.3 | 602.8 | 641.3 |
| .3 | 300.8 | 340.1 | 379.3 | 418.6 | 457.9 | 497.1 | 536.4 | 575.6 | 614.9 | 654.1 |
| .4 | 307.0 | 347.0 | 387.0 | 427.0 | 467.0 | 507.0 | 547.0 | 587.0 | 627.0 | 667.0 |
| .5 | 313.2 | 353.9 | 394.7 | 435.4 | 476.2 | 516.9 | 557.6 | 598.4 | 639.1 | 679.8 |
| .6 | 319.4 | 360.9 | 402.4 | 443.9 | 485.3 | 526.8 | 568.3 | 609.7 | 651.2 | 692.7 |
| .7 | 325.6 | 367.9 | 410.1 | 452.3 | 494.5 | 536.8 | 579.0 | 521.2 | 663.4 | 705.6 |
| .8 | 331.9 | 374.8 | 417.8 | 460.8 | 503.7 | 546.7 | 589.7 | 632.6 | 675.6 | 718.5 |
| .9 | 338.2 | 381.9 | 425.6 | 469.3 | 513.0 | 556.7 | 600.4 | 644.1 | 687.8 | 731.5 |
| 6.0 | 344.4 | 388.9 | 433.3 | 477.8 | 522.2 | 566.7 | 611.1 | 655.6 | 700.0 | 744.4 |

## TABLE XIX.—CU. YDS. PER 100 FT. SLOPES ¼ TO 1.

| Ht. in Ft. | Width of base (=2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 6.1 | 350.8 | 395.9 | 441.1 | 486.3 | 531.5 | 576.7 | 621.9 | 667.0 | 712.2 | 757.4 |
| .2 | 357.1 | 403.0 | 448.9 | 494.9 | 540.8 | 586.7 | 632.6 | 678.6 | 724.5 | 770.4 |
| .3 | 363.4 | 410.1 | 456.8 | 503.4 | 550.1 | 596.8 | 643.4 | 690.1 | 736.8 | 783.4 |
| .4 | 369.8 | 417.2 | 464.6 | 512.0 | 559.4 | 606.8 | 654.2 | 701.6 | 749.1 | 796.5 |
| .5 | 376.2 | 424.3 | 472.5 | 520.6 | 568.8 | 616.9 | 665.1 | 713.2 | 761.4 | 809.5 |
| .6 | 382.6 | 431.4 | 480.3 | 529.2 | 578.1 | 627.0 | 675.9 | 724.8 | 773.7 | 822.6 |
| .7 | 389.0 | 438.6 | 488.2 | 537.9 | 587.5 | 637.1 | 686.8 | 736.4 | 786.0 | 835.6 |
| .8 | 395.4 | 445.8 | 496.1 | 546.5 | 596.9 | 647.3 | 697.6 | 748.0 | 798.4 | 848.7 |
| .9 | 401.9 | 453.0 | 504.1 | 555.2 | 606.3 | 657.4 | 708.5 | 759.6 | 810.8 | 861.9 |
| 7.0 | 408.3 | 460.2 | 512.0 | 563.9 | 615.7 | 667.6 | 719.4 | 771.3 | 823.1 | 875.0 |
| 7.1 | 414.8 | 467.4 | 520.0 | 572.6 | 625.2 | 677.8 | 730.4 | 783.0 | 835.6 | 888.1 |
| .2 | 421.3 | 474.7 | 528.0 | 581.3 | 634.7 | 688.0 | 741.3 | 794.7 | 848.0 | 901.3 |
| .3 | 427.9 | 481.9 | 536.0 | 590.1 | 644.2 | 698.2 | 752.3 | 806.4 | 860.4 | 914.5 |
| .4 | 434.4 | 489.2 | 544.0 | 598.9 | 653.7 | 708.5 | 763.3 | 818.1 | 872.9 | 927.7 |
| .5 | 441.0 | 496.5 | 552.1 | 607.6 | 663.2 | 718.8 | 774.3 | 829.9 | 885.4 | 941.0 |
| .6 | 447.6 | 503.9 | 560.1 | 616.4 | 672.7 | 729.0 | 785.3 | 841.6 | 897.9 | 954.2 |
| .7 | 454.2 | 511.2 | 568.2 | 625.3 | 682.3 | 739.3 | 796.4 | 853.4 | 910.5 | 967.5 |
| .8 | 460.8 | 518.6 | 576.3 | 634.1 | 691.9 | 749.7 | 807.5 | 865.2 | 923.0 | 980.8 |
| .9 | 467.4 | 525.9 | 584.5 | 643.0 | 701.5 | 760.0 | 818.5 | 877.0 | 935.5 | 994.0 |
| 8.0 | 474.1 | 533.3 | 592.6 | 651.9 | 711.1 | 770.4 | 829.6 | 888.9 | 948.2 | 1007.4 |
| 8.1 | 480.8 | 540.8 | 600.8 | 660.8 | 720.7 | 780.7 | 840.7 | 900.7 | 960.7 | 1020.7 |
| .2 | 487.5 | 548.2 | 608.9 | 669.7 | 730.4 | 791.2 | 851.9 | 912.6 | 973.4 | 1034.1 |
| .3 | 494.2 | 555.6 | 617.1 | 678.6 | 740.1 | 801.6 | 863.0 | 924.5 | 986.0 | 1047.5 |
| .4 | 500.9 | 563.1 | 625.3 | 687.6 | 749.8 | 812.0 | 874.2 | 936.4 | 998.7 | 1060.9 |
| .5 | 507.7 | 570.6 | 633.6 | 696.5 | 759.5 | 822.5 | 885.4 | 948.4 | 1011.3 | 1074.3 |
| .6 | 514.4 | 578.1 | 641.8 | 705.5 | 769.2 | 832.9 | 896.6 | 960.3 | 1024.0 | 1087.7 |
| .7 | 521.2 | 585.6 | 650.1 | 714.5 | 779.0 | 843.4 | 907.9 | 972.3 | 1036.7 | 1101.2 |
| .8 | 528.0 | 593.2 | 658.4 | 723.6 | 788.7 | 853.9 | 919.1 | 984.3 | 1049.5 | 1114.6 |
| .9 | 534.9 | 600.8 | 666.7 | 732.6 | 798.5 | 864.5 | 930.4 | 996.3 | 1062.2 | 1128.1 |
| 9.0 | 541.7 | 608.3 | 675.0 | 741.7 | 808.3 | 875.0 | 941.7 | 1008.3 | 1075.0 | 1141.7 |
| 9.1 | 548.6 | 615.9 | 683.3 | 750.8 | 818.2 | 885.6 | 953.0 | 1020.4 | 1087.8 | 1155.2 |
| .2 | 555.4 | 623.6 | 691.7 | 759.9 | 828.0 | 896.2 | 964.3 | 1032.5 | 1100.6 | 1168.8 |
| .3 | 562.3 | 631.2 | 700.1 | 769.0 | 837.9 | 906.8 | 975.6 | 1044.5 | 1113.4 | 1182.3 |
| .4 | 569.2 | 638.8 | 708.5 | 778.1 | 847.7 | 917.4 | 987.0 | 1056.6 | 1126.3 | 1195.9 |
| .5 | 576.2 | 646.5 | 716.9 | 787.3 | 857.6 | 928.0 | 998.4 | 1068.8 | 1141.8 | 1212.2 |
| .6 | 583.1 | 654.2 | 725.3 | 796.4 | 867.6 | 938.7 | 1009.8 | 1089.9 | 1152.0 | 1223.1 |
| .7 | 590.1 | 661.9 | 733.8 | 805.6 | 877.5 | 949.3 | 1021.2 | 1093.0 | 1164.9 | 1236.7 |
| .8 | 597.1 | 669.6 | 742.3 | 814.9 | 887.4 | 960.0 | 1032.6 | 1105.2 | 1177.8 | 1250.4 |
| .9 | 604.1 | 677.4 | 750.8 | 824.1 | 897.4 | 970.8 | 1044.1 | 1117.4 | 1190.7 | 1264.1 |
| 10.0 | 611.2 | 685.2 | 759.3 | 833.3 | 907.4 | 981.5 | 1055.6 | 1129.6 | 1203.7 | 1277.8 |
| 10.1 | 618.2 | 693.0 | 767.8 | 842.6 | 917.4 | 992.2 | 1067.1 | 1141.9 | 1216.7 | 1291.5 |
| .2 | 625.2 | 700.8 | 776.3 | 851.9 | 927.4 | 1003.0 | 1078.6 | 1154.1 | 1229.7 | 1305.2 |
| .3 | 632.3 | 708.6 | 784.9 | 861.2 | 937.5 | 1013.8 | 1090.1 | 1166.4 | 1242.7 | 1319.0 |
| .4 | 639.4 | 716.4 | 793.5 | 870.5 | 947.6 | 1024.6 | 1101.6 | 1178.7 | 1255.7 | 1332.8 |
| .5 | 646.5 | 724.3 | 802.1 | 879.9 | 957.6 | 1035.4 | 1113.2 | 1191.0 | 1268.8 | 1346.5 |
| .6 | 653.7 | 732.2 | 810.7 | 889.2 | 967.7 | 1046.3 | 1124.8 | 1203.3 | 1281.8 | 1360.3 |
| .7 | 660.8 | 740.1 | 819.3 | 898.6 | 977.9 | 1057.1 | 1136.4 | 1215.6 | 1294.9 | 1374.2 |
| .8 | 668.0 | 748.0 | 828.0 | 908.0 | 988.0 | 1068.0 | 1148.0 | 1228.0 | 1308.0 | 1388.2 |
| .9 | 675.2 | 755.9 | 836.7 | 917.4 | 998.2 | 1078.9 | 1159.6 | 1240.4 | 1321.1 | 1401.9 |
| 11.0 | 682.4 | 763.9 | 845.4 | 926.9 | 1008.3 | 1089.8 | 1171.3 | 1252.8 | 1334.3 | 1415.7 |
| 11.1 | 689.6 | 771.9 | 854.1 | 936.3 | 1018.5 | 1100.7 | 1183.0 | 1265.2 | 1347.4 | 1429.6 |
| .2 | 696.9 | 779.9 | 862.8 | 945.8 | 1028.7 | 1111.7 | 1194.7 | 1277.6 | 1360.6 | 1443.5 |
| .3 | 704.2 | 787.9 | 871.6 | 955.3 | 1039.0 | 1122.7 | 1206.4 | 1290.1 | 1373.8 | 1457.5 |
| .4 | 711.5 | 795.9 | 880.3 | 964.8 | 1049.2 | 1133.7 | 1218.1 | 1302.5 | 1387.0 | 1471.4 |
| .5 | 718.8 | 803.9 | 889.1 | 974.3 | 1059.5 | 1144.7 | 1229.9 | 1315.0 | 1400.2 | 1485.4 |
| .6 | 726.1 | 812.0 | 897.9 | 983.9 | 1069.8 | 1155.7 | 1240.6 | 1326.6 | 1412.5 | 1498.4 |
| .7 | 733.4 | 820.1 | 906.8 | 993.4 | 1080.1 | 1166.8 | 1253.4 | 1340.1 | 1426.8 | 1513.4 |
| .8 | 740.8 | 828.2 | 915.6 | 1003.0 | 1090.4 | 1177.8 | 1265.2 | 1352.6 | 1440.0 | 1527.5 |
| .9 | 748.2 | 836.3 | 924.5 | 1012.6 | 1100.8 | 1188.9 | 1277.1 | 1365.2 | 1453.4 | 1541.5 |
| 12.0 | 755.6 | 844.4 | 933.3 | 1022.2 | 1111.1 | 1200.0 | 1288.9 | 1377.8 | 1466.7 | 1555.6 |

| Ht. in Ft. | Width of base (=2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 12.1 | 763.0 | 852.6 | 942.2 | 1031.9 | 1121.5 | 1211.1 | 1300.8 | 1390.4 | 1480.0 | 1559.6 |
| .2 | 770.4 | 860.8 | 951.1 | 1041.5 | 1131.9 | 1222.3 | 1312.6 | 1403.0 | 1493.4 | 1583.7 |
| .3 | 777.9 | 869.0 | 960.1 | 1051.2 | 1142.3 | 1233.4 | 1324.5 | 1415.6 | 1506.7 | 1597.9 |
| .4 | 785.3 | 877.2 | 969.0 | 1060.9 | 1152.7 | 1244.6 | 1336.4 | 1428.3 | 1520.1 | 1612.0 |
| .5 | 792.8 | 885.4 | 978.0 | 1070.6 | 1163.2 | 1255.8 | 1348.4 | 1441.0 | 1533.6 | 1626.1 |
| .6 | 800.4 | 893.7 | 987.0 | 1080.3 | 1173.7 | 1267.0 | 1360.3 | 1453.7 | 1547.0 | 1640.3 |
| .7 | 807.9 | 901.9 | 996.0 | 1090.1 | 1184.2 | 1278.2 | 1372.3 | 1466.4 | 1560.4 | 1654.5 |
| .8 | 815.4 | 910.2 | 1005.0 | 1099.9 | 1194.7 | 1289.5 | 1384.3 | 1479.1 | 1573.9 | 1668.7 |
| .9 | 823.0 | 918.5 | 1014.1 | 1109.6 | 1205.2 | 1300.8 | 1396.3 | 1491.9 | 1587.4 | 1683.0 |
| 13.0 | 830.6 | 926.9 | 1023.1 | 1119.4 | 1215.7 | 1312.0 | 1408.3 | 1504.6 | 1600.9 | 1697.2 |
| 13.1 | 838.2 | 935.2 | 1032.2 | 1129.3 | 1226.3 | 1323.3 | 1420.4 | 1517.4 | 1614.5 | 1711.5 |
| .2 | 845.8 | 943.6 | 1041.3 | 1139.1 | 1236.9 | 1335.7 | 1432.5 | 1530.2 | 1628.0 | 1725.8 |
| .3 | 853.4 | 951.9 | 1050.5 | 1149.0 | 1247.5 | 1346.0 | 1444.5 | 1543.1 | 1641.6 | 1740.1 |
| .4 | 861.1 | 960.3 | 1059.6 | 1158.9 | 1258.1 | 1357.4 | 1456.6 | 1555.9 | 1655.2 | 1754.4 |
| .5 | 868.7 | 968.7 | 1068.8 | 1168.8 | 1268.8 | 1368.8 | 1468.8 | 1568.8 | 1668.8 | 1768.8 |
| .6 | 876.4 | 977.2 | 1077.9 | 1178.7 | 1279.4 | 1380.1 | 1480.9 | 1581.6 | 1682.4 | 1783.1 |
| .7 | 884.2 | 985.6 | 1087.1 | 1188.6 | 1290.1 | 1391.6 | 1493.0 | 1594.5 | 1696.0 | 1797.5 |
| .8 | 891.9 | 994.1 | 1096.3 | 1198.6 | 1300.8 | 1403.0 | 1505.2 | 1607.4 | 1709.7 | 1811.9 |
| .9 | 899.6 | 1002.6 | 1105.6 | 1208.5 | 1311.5 | 1414.4 | 1517.4 | 1620.4 | 1723.3 | 1826.3 |
| 14.0 | 907.4 | 1011.1 | 1114.8 | 1218.5 | 1322.2 | 1425.9 | 1529.6 | 1633.3 | 1737.0 | 1840.7 |
| 14.1 | 915.2 | 1019.6 | 1124.1 | 1228.5 | 1333.0 | 1437.4 | 1541.9 | 1646.3 | 1750.7 | 1855.2 |
| .2 | 923.0 | 1028.2 | 1133.4 | 1238.6 | 1343.7 | 1448.9 | 1554.1 | 1659.3 | 1764.5 | 1869.7 |
| .3 | 930.8 | 1036.7 | 1142.7 | 1248.6 | 1354.5 | 1460.5 | 1566.4 | 1672.3 | 1778.3 | 1884.2 |
| .4 | 938.7 | 1045.3 | 1152.0 | 1258.7 | 1365.3 | 1472.0 | 1578.7 | 1685.3 | 1792.0 | 1898.7 |
| .5 | 946.5 | 1053.9 | 1161.3 | 1268.8 | 1376.2 | 1483.6 | 1591.0 | 1698.4 | 1805.8 | 1913.2 |
| .6 | 954.4 | 1062.6 | 1170.7 | 1278.9 | 1387.0 | 1495.2 | 1603.3 | 1711.5 | 1819.6 | 1927.8 |
| .7 | 962.3 | 1071.2 | 1180.1 | 1289.0 | 1397.9 | 1506.8 | 1615.6 | 1724.5 | 1833.4 | 1942.3 |
| .8 | 970.2 | 1079.9 | 1189.5 | 1299.1 | 1408.7 | 1518.4 | 1628.0 | 1737.6 | 1847.3 | 1956.9 |
| .9 | 978.2 | 1088.5 | 1198.9 | 1309.3 | 1419.6 | 1530.0 | 1640.4 | 1750.7 | 1861.1 | 1971.5 |
| 15.0 | 986.1 | 1097.2 | 1208.3 | 1319.4 | 1430.6 | 1541.7 | 1652.8 | 1763.9 | 1875.0 | 1986.1 |
| 16 | 1067 | 1185 | 1304 | 1422 | 1541 | 1659 | 1778 | 1896 | 2015 | 2133 |
| 17 | 1149 | 1275 | 1401 | 1527 | 1653 | 1779 | 1905 | 2031 | 2157 | 2282 |
| 18 | 1233 | 1367 | 1500 | 1633 | 1767 | 1900 | 2033 | 2167 | 2300 | 2433 |
| 19 | 1319 | 1460 | 1601 | 1742 | 1882 | 2023 | 2164 | 2305 | 2445 | 2586 |
| 20 | 1407 | 1556 | 1704 | 1852 | 2000 | 2148 | 2296 | 2444 | 2593 | 2741 |
| 21 | 1497 | 1654 | 1808 | 1964 | 2119 | 2275 | 2431 | 2586 | 2742 | 2897 |
| 22 | 1589 | 1753 | 1915 | 2078 | 2241 | 2404 | 2567 | 2730 | 2893 | 3056 |
| 23 | 1682 | 1854 | 2023 | 2194 | 2364 | 2534 | 2705 | 2875 | 3045 | 3216 |
| 24 | 1778 | 1956 | 2133 | 2311 | 2489 | 2667 | 2844 | 3022 | 3200 | 3378 |
| 25 | 1875 | 2061 | 2245 | 2431 | 2616 | 2801 | 2986 | 3171 | 3357 | 3542 |
| 26 | 1974 | 2167 | 2359 | 2552 | 2744 | 2937 | 3130 | 3322 | 3515 | 3707 |
| 27 | 2075 | 2275 | 2475 | 2675 | 2875 | 3075 | 3275 | 3475 | 3675 | 3875 |
| 28 | 2178 | 2385 | 2593 | 2800 | 3007 | 3215 | 3422 | 3630 | 3837 | 4044 |
| 29 | 2282 | 2497 | 2712 | 2927 | 3142 | 3356 | 3571 | 3786 | 4001 | 4216 |
| 30 | 2389 | 2611 | 2833 | 3056 | 3278 | 3500 | 3722 | 3944 | 4167 | 4389 |
| 31 | 2497 | 2727 | 2957 | 3186 | 3416 | 3645 | 3875 | 4105 | 4334 | 4564 |
| 32 | 2607 | 2844 | 3082 | 3319 | 3556 | 3793 | 4030 | 4267 | 4504 | 4741 |
| 33 | 2719 | 2964 | 3208 | 3453 | 3697 | 3942 | 4186 | 4431 | 4675 | 4919 |
| 34 | 2833 | 3085 | 3337 | 3589 | 3841 | 4093 | 4344 | 4596 | 4848 | 5100 |
| 35 | 2949 | 3208 | 3468 | 3727 | 3986 | 4245 | 4505 | 4764 | 5023 | 5282 |
| 36 | 3067 | 3333 | 3600 | 3867 | 4133 | 4400 | 4667 | 4933 | 5200 | 5467 |
| 37 | 3186 | 3460 | 3734 | 4008 | 4282 | 4556 | 4831 | 5105 | 5379 | 5653 |
| 38 | 3307 | 3589 | 3870 | 4152 | 4433 | 4715 | 4996 | 5278 | 5559 | 5841 |
| 39 | 3431 | 3719 | 4008 | 4297 | 4586 | 4875 | 5164 | 5453 | 5742 | 6031 |
| 40 | 3556 | 3852 | 4148 | 4444 | 4741 | 5037 | 5333 | 5630 | 5926 | 6222 |
| 41 | 3682 | 3986 | 4290 | 4594 | 4897 | 5201 | 5505 | 5808 | 6112 | 6416 |
| 42 | 3811 | 4122 | 4433 | 4744 | 5056 | 5367 | 5678 | 5989 | 6300 | 6611 |
| 43 | 3942 | 4260 | 4579 | 4897 | 5216 | 5534 | 5853 | 6171 | 6490 | 6808 |
| 44 | 4047 | 4400 | 4726 | 5052 | 5378 | 5704 | 6030 | 6356 | 6682 | 7007 |
| 45 | 4208 | 4541 | 4875 | 5208 | 5542 | 5875 | 6208 | 6542 | 6875 | 7208 |

## TABLE XIX.—CU. YDS. PER 100 FT. SIDE SLOPES ½ TO 1.

| Ht. in Ft. | Width of base (=2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 0.1 | 5.2 | 5.9 | 6.7 | 7.5 | 8.2 | 8.9 | 9.6 | 10.4 | 11.1 | 11.9 |
| .2 | 10.4 | 11.9 | 13.4 | 14.9 | 16.3 | 17.8 | 19.3 | 20.8 | 22.3 | 23.8 |
| .3 | 15.7 | 17.9 | 20.2 | 22.4 | 24.6 | 26.8 | 29.1 | 31.3 | 33.5 | 35.7 |
| .4 | 21.0 | 24.0 | 27.0 | 29.9 | 32.8 | 35.8 | 38.8 | 41.8 | 44.7 | 47.7 |
| .5 | 26.4 | 30.1 | 33.8 | 37.5 | 41.2 | 44.9 | 48.6 | 52.3 | 56.0 | 59.7 |
| .6 | 31.8 | 36.2 | 40.7 | 45.1 | 49.6 | 54.0 | 58.4 | 62.9 | 67.3 | 71.8 |
| .7 | 37.2 | 42.4 | 47.6 | 52.8 | 58.0 | 63.2 | 68.3 | 73.5 | 78.7 | 83.9 |
| .8 | 42.7 | 48.6 | 54.5 | 60.5 | 66.4 | 72.3 | 78.3 | 84.2 | 90.1 | 96.0 |
| .9 | 48.2 | 54.8 | 61.5 | 68.2 | 74.8 | 81.5 | 88.2 | 94.8 | 101.5 | 108.2 |
| 1.0 | 53.7 | 61.1 | 68.5 | 75.9 | 83.3 | 90.7 | 98.2 | 105.6 | 113.0 | 120.4 |
| 1.1 | 59.3 | 67.4 | 75.6 | 83.7 | 91.9 | 100.0 | 108.2 | 116.3 | 124.5 | 132.6 |
| .2 | 64.9 | 73.8 | 82.7 | 91.6 | 100.5 | 109.3 | 118.2 | 127.1 | 136.0 | 144.9 |
| .3 | 70.5 | 80.2 | 89.8 | 99.4 | 109.1 | 118.7 | 128.3 | 138.0 | 147.6 | 157.2 |
| .4 | 76.2 | 86.6 | 97.0 | 107.3 | 117.7 | 128.1 | 138.4 | 148.8 | 159.2 | 169.6 |
| .5 | 81.9 | 93.1 | 104.2 | 115.3 | 126.4 | 137.5 | 148.6 | 159.7 | 170.8 | 181.9 |
| .6 | 87.7 | 100.0 | 111.4 | 123.3 | 135.1 | 147.0 | 158.8 | 170.7 | 182.5 | 194.4 |
| .7 | 93.5 | 106.1 | 118.7 | 131.3 | 143.9 | 156.5 | 169.0 | 181.6 | 194.2 | 206.8 |
| .8 | 99.3 | 112.7 | 126.0 | 139.3 | 152.7 | 166.0 | 179.3 | 192.7 | 206.0 | 219.3 |
| .9 | 105.2 | 119.3 | 133.3 | 147.4 | 161.5 | 175.6 | 189.6 | 203.7 | 217.8 | 231.8 |
| 2.0 | 111.1 | 125.9 | 140.7 | 155.5 | 170.4 | 185.2 | 200.0 | 214.8 | 229.6 | 244.4 |
| 2.1 | 117.1 | 132.6 | 148.2 | 163.7 | 179.3 | 194.8 | 210.4 | 225.9 | 241.5 | 257.1 |
| .2 | 123.0 | 139.3 | 155.6 | 171.9 | 188.2 | 204.5 | 220.8 | 237.1 | 253.4 | 269.7 |
| .3 | 129.1 | 146.1 | 163.1 | 180.2 | 197.2 | 214.2 | 231.2 | 248.3 | 265.3 | 282.3 |
| .4 | 135.1 | 152.9 | 170.7 | 188.4 | 206.2 | 224.0 | 241.7 | 259.5 | 277.3 | 295.1 |
| .5 | 141.2 | 159.7 | 178.2 | 196.7 | 215.2 | 233.8 | 252.3 | 270.8 | 289.3 | 307.8 |
| .6 | 147.3 | 166.6 | 185.9 | 205.1 | 223.4 | 242.6 | 261.9 | 281.2 | 300.4 | 319.7 |
| .7 | 153.5 | 173.5 | 193.5 | 213.5 | 233.5 | 253.5 | 273.5 | 293.6 | 313.6 | 333.7 |
| .8 | 159.7 | 180.4 | 201.2 | 221.9 | 242.7 | 263.4 | 284.1 | 304.9 | 325.6 | 346.4 |
| .9 | 165.9 | 187.4 | 208.9 | 230.4 | 251.9 | 273.3 | 294.8 | 316.3 | 337.8 | 359.3 |
| 3.0 | 172.2 | 194.4 | 216.7 | 238.9 | 261.1 | 283.3 | 305.6 | 327.8 | 350.0 | 372.2 |
| 3.1 | 178.5 | 201.5 | 224.5 | 247.4 | 270.4 | 293.3 | 316.3 | 339.3 | 362.2 | 385.2 |
| .2 | 184.9 | 208.6 | 232.3 | 256.0 | 279.7 | 303.4 | 327.1 | 350.8 | 374.5 | 398.2 |
| .3 | 191.3 | 215.7 | 240.2 | 264.6 | 289.1 | 313.5 | 337.9 | 362.4 | 386.8 | 411.3 |
| .4 | 197.7 | 222.9 | 248.1 | 273.2 | 298.4 | 323.6 | 348.8 | 374.0 | 399.2 | 424.4 |
| .5 | 204.2 | 230.1 | 256.0 | 281.9 | 307.9 | 333.8 | 359.7 | 385.6 | 411.5 | 437.5 |
| .6 | 210.7 | 237.3 | 264.0 | 290.7 | 317.3 | 344.0 | 370.7 | 397.3 | 424.0 | 450.7 |
| .7 | 217.2 | 244.6 | 272.0 | 299.4 | 326.8 | 354.2 | 381.6 | 409.0 | 436.4 | 463.8 |
| .8 | 223.8 | 251.9 | 280.1 | 308.2 | 336.3 | 364.5 | 392.6 | 420.8 | 448.9 | 477.1 |
| .9 | 230.4 | 259.3 | 288.2 | 317.0 | 345.9 | 374.8 | 403.7 | 432.6 | 461.4 | 490.8 |
| 4.0 | 237.0 | 266.7 | 296.3 | 325.9 | 355.5 | 385.1 | 414.8 | 444.4 | 474.0 | 503.7 |
| 4.1 | 243.7 | 274.1 | 304.4 | 334.8 | 365.2 | 395.5 | 425.9 | 456.2 | 486.6 | 517.0 |
| .2 | 250.4 | 281.5 | 312.6 | 343.7 | 374.8 | 405.9 | 437.0 | 468.2 | 499.3 | 530.4 |
| .3 | 257.2 | 289.1 | 320.9 | 352.8 | 384.6 | 416.5 | 448.3 | 480.2 | 512.0 | 543.9 |
| .4 | 264.0 | 296.6 | 329.2 | 361.8 | 394.4 | 427.0 | 459.5 | 492.1 | 524.7 | 557.3 |
| .5 | 270.8 | 304.2 | 337.5 | 370.8 | 404.2 | 437.5 | 470.8 | 504.1 | 537.5 | 570.8 |
| .6 | 277.7 | 311.8 | 345.8 | 379.9 | 414.0 | 448.1 | 482.1 | 516.2 | 550.3 | 584.3 |
| .7 | 284.6 | 319.4 | 354.2 | 389.0 | 423.8 | 458.7 | 493.5 | 528.3 | 563.1 | 597.9 |
| .8 | 291.6 | 327.1 | 362.7 | 398.2 | 433.8 | 469.3 | 504.9 | 540.4 | 576.0 | 611.5 |
| .9 | 298.5 | 334.8 | 371.1 | 407.4 | 443.7 | 480.0 | 516.3 | 552.6 | 588.9 | 625.2 |
| 5.0 | 305.6 | 342.6 | 379.6 | 416.7 | 453.7 | 490.7 | 527.7 | 564.8 | 601.8 | 638.9 |
| 5.1 | 312.6 | 350.4 | 388.2 | 425.9 | 463.7 | 501.5 | 539.3 | 577.0 | 614.8 | 652.6 |
| .2 | 319.7 | 358.2 | 396.7 | 435.2 | 473.8 | 512.3 | 550.8 | 589.3 | 627.8 | 666.3 |
| .3 | 326.8 | 366.1 | 405.3 | 444.6 | 483.8 | 523.1 | 562.3 | 601.6 | 640.8 | 680.1 |
| .4 | 334.0 | 374.0 | 414.0 | 454.0 | 494.0 | 534.0 | 573.9 | 613.9 | 653.9 | 693.9 |
| .5 | 341.2 | 381.9 | 422.7 | 463.4 | 504.1 | 544.9 | 585.6 | 626.3 | 667.0 | 707.8 |
| .6 | 348.4 | 389.9 | 431.4 | 472.9 | 514.3 | 555.8 | 597.3 | 638.7 | 680.2 | 721.7 |
| .7 | 355.7 | 397.9 | 440.2 | 482.4 | 524.6 | 566.8 | 609.0 | 651.3 | 693.5 | 735.7 |
| .8 | 363.0 | 406.0 | 449.0 | 491.2 | 534.9 | 577.8 | 620.8 | 663.8 | 706.7 | 749.7 |
| .9 | 370.4 | 414.1 | 457.8 | 501.5 | 545.2 | 588.9 | 632.6 | 676.3 | 720.0 | 763.7 |
| 6.0 | 377.8 | 422.2 | 466.7 | 511.1 | 555.6 | 600.0 | 644.4 | 688.9 | 723.3 | 777.8 |

| Ht. in Ft. | Width of base ( =2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 6.1 | 385.2 | 430.4 | 475.6 | 520.7 | 565.9 | 611.1 | 656.3 | 701.5 | 746.7 | 791.9 |
| .2 | 392.7 | 438.6 | 484.5 | 530.5 | 576.4 | 622.3 | 668.3 | 714.2 | 760.1 | 806.1 |
| .3 | 400.2 | 446.8 | 493.5 | 540.2 | 586.4 | 633.5 | 680.2 | 726.8 | 773.5 | 820.2 |
| .4 | 407.7 | 455.1 | 502.5 | 549.9 | 597.3 | 644.7 | 692.1 | 739.5 | 787.0 | 834.4 |
| .5 | 415.3 | 463.4 | 511.6 | 559.7 | 607.9 | 656.0 | 704.2 | 752.3 | 800.5 | 848.6 |
| .6 | 422.9 | 471.8 | 520.7 | 569.6 | 618.5 | 667.3 | 716.2 | 765.1 | 814.0 | 862.9 |
| .7 | 430.5 | 480.2 | 529.8 | 579.4 | 629.1 | 678.7 | 728.3 | 778.0 | 827.6 | 877.2 |
| .8 | 438.2 | 488.6 | 539.0 | 589.0 | 639.7 | 690.1 | 740.4 | 790.8 | 841.2 | 891.6 |
| .9 | 445.9 | 497.0 | 548.2 | 599.3 | 650.4 | 701.5 | 752.6 | 803.7 | 854.8 | 905.9 |
| 7.0 | 453.7 | 506.6 | 558.4 | 610.3 | 662.1 | 714.0 | 765.8 | 817.7 | 869.5 | 921.4 |
| 7.1 | 461.5 | 514.1 | 566.7 | 619.3 | 671.9 | 724.5 | 777.0 | 829.6 | 882.2 | 934.8 |
| .2 | 469.3 | 522.7 | 576.0 | 629.3 | 682.7 | 736.0 | 789.3 | 842.6 | 896.0 | 949.3 |
| .3 | 477.2 | 531.3 | 585.3 | 639.4 | 693.5 | 747.6 | 801.6 | 855.7 | 909.8 | 963.9 |
| .4 | 485.1 | 539.9 | 594.7 | 649.5 | 704.4 | 759.2 | 814.0 | 868.8 | 923.6 | 978.4 |
| .5 | 493.1 | 548.6 | 604.2 | 659.7 | 715.3 | 770.8 | 826.4 | 882.0 | 937.5 | 993.1 |
| .6 | 501.0 | 557.3 | 613.6 | 669.9 | 726.2 | 782.5 | 838.8 | 895.1 | 951.4 | 1007.7 |
| .7 | 509.1 | 566.1 | 623.1 | 680.2 | 737.2 | 794.3 | 851.3 | 908.3 | 965.4 | 1022.4 |
| .8 | 517.1 | 574.9 | 632.7 | 690.5 | 748.2 | 806.0 | 863.8 | 921.6 | 979.3 | 1037.1 |
| .9 | 525.2 | 583.7 | 642.2 | 700.7 | 759.2 | 817.8 | 876.3 | 934.8 | 993.3 | 1051.8 |
| 8.0 | 533.3 | 592.6 | 651.9 | 711.1 | 770.4 | 829.6 | 888.9 | 948.2 | 1007.4 | 1066.7 |
| 8.1 | 541.5 | 601.5 | 661.5 | 721.5 | 781.5 | 841.5 | 901.5 | 961.5 | 1021.5 | 1081.5 |
| .2 | 549.7 | 610.4 | 671.2 | 731.9 | 792.7 | 853.4 | 914.1 | 974.9 | 1035.6 | 1096.4 |
| .3 | 557.9 | 619.4 | 680.9 | 742.4 | 803.9 | 865.3 | 926.8 | 988.3 | 1049.8 | 1111.3 |
| .4 | 566.2 | 628.4 | 690.7 | 752.9 | 815.1 | 877.3 | 939.5 | 1001.8 | 1064.0 | 1126.2 |
| .5 | 574.5 | 637.5 | 700.5 | 763.4 | 826.4 | 889.3 | 952.3 | 1015.3 | 1078.2 | 1141.2 |
| .6 | 582.9 | 646.6 | 710.3 | 774.0 | 837.7 | 901.4 | 965.1 | 1028.8 | 1092.5 | 1156.2 |
| .7 | 591.3 | 655.7 | 720.2 | 784.6 | 849.0 | 913.5 | 977.9 | 1042.4 | 1106.8 | 1171.3 |
| .8 | 599.7 | 664.9 | 730.1 | 795.2 | 860.4 | 925.6 | 990.8 | 1056.0 | 1121.1 | 1186.3 |
| .9 | 608.2 | 674.1 | 740.0 | 805.9 | 871.9 | 937.8 | 1003.7 | 1069.6 | 1135.5 | 1201.5 |
| 9.0 | 616.7 | 683.3 | 750.0 | 816.7 | 883.3 | 950.0 | 1016.7 | 1083.3 | 1150.0 | 1216.7 |
| 9.1 | 625.2 | 692.6 | 760.0 | 827.4 | 894.8 | 962.3 | 1029.7 | 1097.1 | 1164.5 | 1231.9 |
| .2 | 633.8 | 701.9 | 770.1 | 838.2 | 906.4 | 974.5 | 1042.7 | 1110.8 | 1179.0 | 1247.1 |
| .3 | 642.4 | 711.3 | 780.2 | 849.1 | 918.0 | 986.8 | 1055.7 | 1124.6 | 1193.5 | 1262.4 |
| .4 | 651.0 | 720.7 | 790.3 | 859.9 | 929.6 | 999.2 | 1068.8 | 1138.5 | 1208.1 | 1277.7 |
| .5 | 659.7 | 730.1 | 800.5 | 870.8 | 941.2 | 1011.6 | 1081.9 | 1152.3 | 1222.7 | 1293.0 |
| .6 | 668.4 | 739.5 | 810.7 | 881.8 | 852.9 | 1024.0 | 1095.1 | 1166.2 | 1237.3 | 1308.4 |
| .7 | 677.2 | 749.1 | 820.9 | 892.8 | 864.6 | 1036.5 | 1108.3 | 1180.2 | 1252.0 | 1323.9 |
| .8 | 686.0 | 758.6 | 831.2 | 903.8 | 976.4 | 1049.0 | 1121.5 | 1194.1 | 1266.7 | 1339.3 |
| .9 | 694.8 | 768.2 | 841.5 | 914.8 | 988.2 | 1061.5 | 1134.8 | 1208.1 | 1281.5 | 1354.8 |
| 10.0 | 703.7 | 777.8 | 851.8 | 925.9 | 1000.0 | 1074.1 | 1148.1 | 1222.2 | 1296.3 | 1370.4 |
| 10.1 | 712.6 | 787.4 | 862.2 | 937.1 | 1011.9 | 1086.7 | 1161.5 | 1236.3 | 1311.2 | 1386.0 |
| .2 | 721.5 | 797.1 | 872.7 | 948.2 | 1023.8 | 1099.3 | 1174.9 | 1250.5 | 1326.0 | 1401.6 |
| .3 | 730.6 | 806.9 | 883.2 | 959.5 | 1035.8 | 1112.1 | 1188.4 | 1264.7 | 1341.0 | 1417.3 |
| .4 | 739.6 | 816.6 | 893.6 | 970.7 | 1047.7 | 1124.8 | 1201.8 | 1278.8 | 1355.9 | 1432.9 |
| .5 | 748.6 | 826.4 | 904.2 | 982.0 | 1059.8 | 1137.5 | 1215.3 | 1293.1 | 1370.9 | 1448.7 |
| .6 | 757.7 | 836.2 | 914.7 | 993.2 | 1071.8 | 1150.3 | 1228.8 | 1307.3 | 1385.8 | 1464.4 |
| .7 | 766.9 | 846.1 | 925.4 | 1004.6 | 1083.9 | 1163.2 | 1242.4 | 1321.7 | 1400.9 | 1480.2 |
| .8 | 776.0 | 856.0 | 936.0 | 1006.0 | 1096.0 | 1176.0 | 1256.0 | 1336.0 | 1416.0 | 1496.0 |
| .9 | 785.2 | 866.0 | 946.7 | 1027.4 | 1108.2 | 1188.9 | 1269.7 | 1350.4 | 1431.1 | 1511.9 |
| 11.0 | 794.4 | 875.9 | 957.4 | 1038.9 | 1120.4 | 1201.8 | 1283.3 | 1364.8 | 1446.3 | 1527.8 |
| 11.1 | 803.7 | 886.0 | 968.2 | 1050.4 | 1132.6 | 1214.8 | 1297.1 | 1379.3 | 1461.5 | 1543.7 |
| .2 | 813.0 | 896.0 | 979.0 | 1061.9 | 1144.9 | 1227.8 | 1310.8 | 1393.8 | 1476.7 | 1559.7 |
| .3 | 822.4 | 906.1 | 989.8 | 1073.5 | 1157.2 | 1240.9 | 1324.6 | 1408.3 | 1492.0 | 1575.7 |
| .4 | 831.8 | 916.2 | 1000.7 | 1085.1 | 1169.6 | 1254.0 | 1338.5 | 1422.9 | 1507.3 | 1591.8 |
| .5 | 841.2 | 926.4 | 1010.6 | 1095.8 | 1180.9 | 1266.1 | 1351.3 | 1436.5 | 1521.7 | 1606.8 |
| .6 | 850.7 | 936.6 | 1022.5 | 1108.5 | 1194.4 | 1280.3 | 1362.3 | 1452.2 | 1538.1 | 1624.1 |
| .7 | 860.2 | 946.9 | 1033.5 | 1120.2 | 1206.9 | 1293.5 | 1380.2 | 1466.9 | 1553.5 | 1640.2 |
| .8 | 869.7 | 957.1 | 1044.5 | 1131.9 | 1219.3 | 1306.7 | 1394.1 | 1481.5 | 1568.9 | 1656.3 |
| .9 | 879.3 | 967.4 | 1055.6 | 1143.7 | 1231.9 | 1320.0 | 1408.2 | 1496.3 | 1584.5 | 1672.6 |
| 1.20 | 888.9 | 977.8 | 1066.7 | 1155.6 | 1244.4 | 1333.3 | 1422.2 | 1511.1 | 1600.0 | 1688.9 |

| Ht. in Ft. | Width of base (=2$b$) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 12.1 | 898.5 | 988.2 | 1077.8 | 1167.4 | 1257.1 | 1346.7 | 1436.3 | 1526.0 | 1615.6 | 1705.2 |
| .2 | 908.2 | 998.6 | 1089.0 | 1179.3 | 1269.7 | 1360.1 | 1450.4 | 1540.8 | 1631.2 | 1721.6 |
| .3 | 917.9 | 1009.1 | 1100.2 | 1191.3 | 1282.4 | 1373.5 | 1464.6 | 1555.7 | 1646.8 | 1737.9 |
| .4 | 927.7 | 1019.6 | 1111.4 | 1203.3 | 1295.1 | 1387.0 | 1478.8 | 1570.7 | 1662.5 | 1754.4 |
| .5 | 937.5 | 1030.1 | 1122.7 | 1215.3 | 1307.9 | 1400.5 | 1493.0 | 1585.6 | 1678.2 | 1770.8 |
| .6 | 947.3 | 1040.7 | 1134.0 | 1227.3 | 1320.7 | 1414.0 | 1507.3 | 1600.6 | 1694.0 | 1787.3 |
| .7 | 957.2 | 1051.3 | 1145.3 | 1239.4 | 1333.5 | 1427.6 | 1521.6 | 1615.7 | 1709.8 | 1803.8 |
| .8 | 967.1 | 1061.9 | 1156.7 | 1251.5 | 1346.4 | 1441.2 | 1536.0 | 1630.8 | 1725.6 | 1820.4 |
| .9 | 977.1 | 1072.6 | 1168.2 | 1263.7 | 1359.3 | 1454.9 | 1550.4 | 1646.0 | 1741.5 | 1837.1 |
| 13.0 | 987.0 | 1083.3 | 1179.6 | 1275.9 | 1372.2 | 1468.5 | 1564.8 | 1661.1 | 1757.4 | 1853.7 |
| 13.1 | 997.1 | 1094.1 | 1191.1 | 1288.2 | 1385.2 | 1482.3 | 1579.3 | 1676.3 | 1773.4 | 1870.4 |
| .2 | 1007.1 | 1104.9 | 1202.7 | 1300.4 | 1398.2 | 1496.0 | 1593.8 | 1691.6 | 1789.3 | 1887.1 |
| .3 | 1017.2 | 1115.7 | 1214.3 | 1312.8 | 1411.3 | 1509.8 | 1608.3 | 1706.9 | 1805.4 | 1903.9 |
| .4 | 1027.3 | 1126.6 | 1225.9 | 1325.1 | 1424.4 | 1523.6 | 1622.9 | 1722.2 | 1821.4 | 1920.7 |
| .5 | 1037.5 | 1137.5 | 1237.5 | 1337.5 | 1437.5 | 1537.5 | 1637.5 | 1737.5 | 1837.5 | 1937.5 |
| .6 | 1047.7 | 1148.5 | 1249.2 | 1349.9 | 1450.7 | 1551.4 | 1652.2 | 1752.9 | 1853.6 | 1954.4 |
| .7 | 1057.9 | 1159.4 | 1260.9 | 1362.4 | 1463.9 | 1565.4 | 1668.8 | 1768.3 | 1869.8 | 1971.3 |
| .8 | 1068.2 | 1170.4 | 1272.7 | 1374.9 | 1477.1 | 1579.3 | 1681.5 | 1783.8 | 1886.0 | 1988.2 |
| .9 | 1078.5 | 1182.2 | 1285.9 | 1389.6 | 1493.3 | 1597.0 | 1700.7 | 1804.4 | 1908.1 | 2011.8 |
| 14.0 | 1088.9 | 1192.6 | 1296.3 | 1400.0 | 1503.7 | 1607.4 | 1711.1 | 1814.8 | 1918.5 | 2022.2 |
| 14.1 | 1099.3 | 1203.7 | 1308.1 | 1412.6 | 1517.0 | 1621.5 | 1725.9 | 1830.4 | 1934.8 | 2039.3 |
| .2 | 1109.7 | 1214.9 | 1320.1 | 1425.3 | 1530.5 | 1635.6 | 1740.8 | 1846.0 | 1951.2 | 2056.4 |
| .3 | 1120.2 | 1226.1 | 1332.0 | 1437.9 | 1543.9 | 1649.8 | 1755.7 | 1861.7 | 1967.6 | 2073.5 |
| .4 | 1130.7 | 1237.3 | 1344.0 | 1450.7 | 1557.3 | 1664.0 | 1770.7 | 1877.3 | 1984.0 | 2090.7 |
| .5 | 1141.2 | 1248.6 | 1356.0 | 1463.4 | 1570.8 | 1678.2 | 1785.7 | 1893.1 | 2000.5 | 2107.9 |
| .6 | 1151.8 | 1259.9 | 1368.1 | 1476.2 | 1584.4 | 1692.5 | 1800.7 | 1908.8 | 2017.0 | 2125.1 |
| .7 | 1162.4 | 1271.3 | 1380.2 | 1489.1 | 1597.9 | 1706.8 | 1815.7 | 1924.6 | 2033.5 | 2142.4 |
| .8 | 1173.0 | 1282.7 | 1392.3 | 1501.9 | 1611.6 | 1721.2 | 1830.8 | 1940.4 | 2050.1 | 2159.7 |
| .9 | 1183.7 | 1294.1 | 1404.5 | 1514.8 | 1625.2 | 1735.6 | 1845.9 | 1956.3 | 2066.7 | 2177.1 |
| 15.0 | 1194.4 | 1305.6 | 1416.7 | 1527.8 | 1638.9 | 1750.0 | 1861.1 | 1972.2 | 2083.3 | 2194.4 |
| 16 | 1304 | 1422 | 1541 | 1659 | 1779 | 1896 | 2015 | 2133 | 2252 | 2370 |
| 17 | 1417 | 1543 | 1669 | 1794 | 1920 | 2046 | 2172 | 2298 | 2424 | 2550 |
| 18 | 1533 | 1667 | 1800 | 1933 | 2067 | 2200 | 2333 | 2467 | 2600 | 2733 |
| 19 | 1654 | 1794 | 1935 | 2076 | 2217 | 2357 | 2498 | 2639 | 2780 | 2920 |
| 20 | 1778 | 1926 | 2074 | 2222 | 2370 | 2519 | 2667 | 2815 | 2963 | 3111 |
| 21 | 1906 | 2061 | 2217 | 2372 | 2528 | 2683 | 2839 | 2994 | 3150 | 3306 |
| 22 | 2037 | 2200 | 2363 | 2526 | 2689 | 2852 | 3015 | 3178 | 3341 | 3504 |
| 23 | 2172 | 2343 | 2513 | 2683 | 2854 | 3024 | 3194 | 3365 | 3535 | 3706 |
| 24 | 2311 | 2489 | 2667 | 2844 | 3022 | 3200 | 3378 | 3556 | 3733 | 3911 |
| 25 | 2454 | 2639 | 2824 | 3009 | 3194 | 3380 | 3565 | 3750 | 3935 | 4120 |
| 26 | 2600 | 2793 | 2985 | 3178 | 3370 | 3563 | 3756 | 3948 | 4141 | 4333 |
| 27 | 2750 | 2950 | 3150 | 3350 | 3550 | 3750 | 3950 | 4150 | 4350 | 4550 |
| 28 | 2904 | 3111 | 3319 | 3526 | 3733 | 3941 | 4148 | 4356 | 4563 | 4770 |
| 29 | 3061 | 3276 | 3491 | 3706 | 3920 | 4135 | 4350 | 4565 | 4780 | 4994 |
| 30 | 3222 | 3444 | 3667 | 3889 | 4111 | 4333 | 4556 | 4778 | 5000 | 5222 |
| 31 | 3387 | 3617 | 3846 | 4076 | 4306 | 4535 | 4765 | 4994 | 5224 | 5454 |
| 32 | 3556 | 3793 | 4030 | 4267 | 4504 | 4741 | 4978 | 5215 | 5452 | 5689 |
| 33 | 3728 | 3972 | 4217 | 4461 | 4706 | 4950 | 5194 | 5439 | 5683 | 5928 |
| 34 | 3904 | 4156 | 4407 | 4659 | 4911 | 5163 | 5415 | 5667 | 5919 | 6170 |
| 35 | 4083 | 4343 | 4602 | 4861 | 5120 | 5380 | 5639 | 5898 | 6157 | 6417 |
| 36 | 4267 | 4533 | 4800 | 5067 | 5333 | 5600 | 5867 | 6133 | 6400 | 6667 |
| 37 | 4454 | 4728 | 5002 | 5276 | 5550 | 5824 | 6098 | 6372 | 6646 | 6920 |
| 38 | 4644 | 4926 | 5207 | 5489 | 5770 | 6052 | 6333 | 6615 | 6896 | 7178 |
| 39 | 4839 | 5128 | 5417 | 5706 | 5994 | 6283 | 6572 | 6861 | 7150 | 7439 |
| 40 | 5037 | 5333 | 5630 | 5926 | 6222 | 6519 | 6815 | 7111 | 7407 | 7704 |
| 41 | 5239 | 5543 | 5846 | 6150 | 6454 | 6757 | 7061 | 7365 | 7679 | 7982 |
| 42 | 5444 | 5756 | 6067 | 6378 | 6689 | 7000 | 7311 | 7622 | 7933 | 8244 |
| 43 | 5654 | 5972 | 6291 | 6609 | 6928 | 7246 | 7565 | 7883 | 8202 | 8520 |
| 44 | 5867 | 6193 | 6519 | 6844 | 7170 | 7496 | 7822 | 8148 | 8474 | 8800 |
| 45 | 6083 | 6417 | 6750 | 7083 | 7417 | 7750 | 8083 | 8417 | 8750 | 9083 |

| Ht. in Ft. | Width of base ($=2b$) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 0.1 | 5.2 | 6.0 | 6.7 | 7.4 | 8.2 | 8.9 | 9.7 | 10.4 | 11.1 | 11.9 |
| .2 | 10.5 | 12.0 | 13.5 | 15.0 | 16.4 | 17.9 | 19.4 | 20.9 | 22.4 | 23.9 |
| .3 | 15.9 | 18.1 | 20.3 | 22.6 | 24.8 | 27.0 | 29.2 | 31.4 | 33.7 | 35.9 |
| .4 | 21.3 | 24.3 | 27.3 | 30.2 | 33.2 | 36.1 | 39.1 | 42.1 | 45.0 | 48.0 |
| .5 | 26.9 | 30.6 | 34.3 | 38.0 | 41.7 | 45.4 | 49.1 | 52.8 | 56.5 | 60.2 |
| .6 | 32.4 | 36.9 | 41.3 | 45.8 | 50.2 | 54.7 | 59.1 | 63.5 | 68.0 | 72.4 |
| .7 | 38.1 | 43.3 | 48.5 | 53.7 | 58.9 | 64.1 | 69.3 | 74.4 | 79.6 | 84.8 |
| .8 | 43.9 | 49.8 | 55.7 | 61.6 | 67.6 | 73.5 | 79.4 | 85.4 | 91.3 | 97.2 |
| .9 | 49.7 | 56.3 | 63.0 | 69.7 | 76.3 | 83.0 | 89.7 | 96.3 | 103.0 | 109.7 |
| 1.0 | 55.6 | 63.0 | 70.4 | 77.8 | 85.2 | 92.6 | 100.0 | 107.4 | 114.8 | 122.3 |
| 1.1 | 61.5 | 69.7 | 77.8 | 86.0 | 94.1 | 102.3 | 110.4 | 118.6 | 126.7 | 134.9 |
| .2 | 67.6 | 76.5 | 85.3 | 94.2 | 103.1 | 112.0 | 120.9 | 129.8 | 138.7 | 147.6 |
| .3 | 73.7 | 83.3 | 92.9 | 102.6 | 112.2 | 121.8 | 131.5 | 141.1 | 150.7 | 160.3 |
| .4 | 79.8 | 90.2 | 100.6 | 110.9 | 121.3 | 131.7 | 142.1 | 152.4 | 162.8 | 173.2 |
| .5 | 86.1 | 97.2 | 108.3 | 119.4 | 130.6 | 141.7 | 152.8 | 163.9 | 175.0 | 186.1 |
| .6 | 92.4 | 104.3 | 116.1 | 128.0 | 139.8 | 151.7 | 163.5 | 175.4 | 187.2 | 199.1 |
| .7 | 98.9 | 111.4 | 124.0 | 136.6 | 149.2 | 161.8 | 174.4 | 187.0 | 199.6 | 212.2 |
| .8 | 105.3 | 118.7 | 132.0 | 145.3 | 158.7 | 172.0 | 185.3 | 198.7 | 212.0 | 225.3 |
| .9 | 111.9 | 126.0 | 140.0 | 154.1 | 168.2 | 182.2 | 196.3 | 210.4 | 224.5 | 238.5 |
| 2.0 | 118.5 | 133.3 | 148.1 | 163.0 | 177.8 | 192.6 | 207.4 | 222.2 | 237.0 | 251.8 |
| 2.1 | 125.2 | 140.8 | 156.3 | 171.9 | 187.4 | 203.0 | 218.5 | 234.1 | 249.6 | 265.2 |
| .2 | 132.0 | 148.3 | 164.6 | 180.9 | 197.2 | 213.5 | 229.7 | 246.0 | 262.3 | 278.6 |
| .3 | 138.9 | 155.9 | 172.9 | 189.9 | 207.0 | 224.0 | 241.0 | 258.1 | 275.1 | 292.1 |
| 4 | 145.8 | 163.6 | 181.3 | 199.1 | 216.9 | 234.6 | 252.4 | 270.2 | 287.9 | 305.7 |
| .5 | 152.8 | 171.3 | 189.8 | 208.3 | 226.8 | 245.3 | 263.8 | 282.4 | 300.9 | 319.4 |
| .6 | 159.8 | 179.1 | 198.4 | 217.6 | 236.9 | 256.1 | 275.4 | 294.7 | 313.9 | 333.2 |
| .7 | 167.0 | 187.0 | 207.0 | 227.0 | 247.0 | 267.0 | 287.0 | 307.0 | 327.0 | 347.0 |
| .8 | 174.2 | 195.0 | 215.7 | 236.4 | 257.2 | 277.9 | 298.7 | 319.4 | 340.1 | 360.9 |
| .9 | 181.5 | 203.0 | 224.5 | 246.0 | 267.4 | 288.9 | 310.4 | 331.9 | 353.4 | 374.8 |
| 3.0 | 188.9 | 211.1 | 233.3 | 255.6 | 277.8 | 300.0 | 322.2 | 344.4 | 366.7 | 388.9 |
| 3.1 | 196.3 | 219.3 | 242.3 | 265.2 | 288.2 | 311.1 | 334.1 | 357.1 | 380,0 | 403.0 |
| .2 | 203.9 | 227.6 | 251.3 | 275.0 | 298.7 | 322.4 | 346.1 | 369.8 | 393.5 | 417.2 |
| .3 | 211.4 | 235.9 | 260.3 | 284.8 | 309.2 | 333.7 | 358.1 | 382.5 | 407.0 | 431.4 |
| .4 | 219.1 | 244.3 | 269.5 | 294.7 | 319.8 | 345.0 | 370.2 | 395.4 | 420.6 | 445.7 |
| .5 | 226.9 | 252.8 | 278.7 | 304.6 | 330.5 | 356.5 | 382.4 | 408.3 | 434.2 | 460.1 |
| .6 | 234.7 | 261.3 | 288.0 | 314.7 | 341.3 | 368.0 | 394.6 | 421.3 | 448.0 | 474.6 |
| .7 | 242.6 | 270.0 | 297.4 | 324.8 | 352.2 | 379.6 | 407.0 | 434.4 | 461.8 | 489.2 |
| .8 | 250.5 | 278.7 | 306.8 | 334.9 | 363.1 | 391.2 | 419.4 | 447.6 | 475.7 | 503.9 |
| .9 | 258.6 | 287.4 | 316.3 | 345.2 | 374.1 | 403.0 | 431.8 | 460.7 | 489.6 | 518.5 |
| 4.0 | 266.7 | 296.3 | 325.9 | 355.5 | 385.2 | 414.8 | 444.4 | 474.0 | 503.6 | 533.3 |
| 4.1 | 274.9 | 305.2 | 335.6 | 365.9 | 396.3 | 426.7 | 457.0 | 487.4 | 517.7 | 548.1 |
| .2 | 283.1 | 314.2 | 345.3 | 376.4 | 407.5 | 438.6 | 469.7 | 500.8 | 531.9 | 563.0 |
| .3 | 291.4 | 323.3 | 355.1 | 387.0 | 418.8 | 450.7 | 482.5 | 514.4 | 546.2 | 578.1 |
| .4 | 299.9 | 332.4 | 365.0 | 397.6 | 430.2 | 462.8 | 495.4 | 528.0 | 560.6 | 593.2 |
| .5 | 308.3 | 341.7 | 375.0 | 408.3 | 441.7 | 475.0 | 508.3 | 541.6 | 575.0 | 608.3 |
| .6 | 316.9 | 351.0 | 385.0 | 419.1 | 453.2 | 487.2 | 521.3 | 555.4 | 589.5 | 623.5 |
| .7 | 325.5 | 360.3 | 395.1 | 430.0 | 464.8 | 499.6 | 534.4 | 569.2 | 604.0 | 638.8 |
| .8 | 334.2 | 369.8 | 405.3 | 440.9 | 476.4 | 512.0 | 547.5 | 583.1 | 618.6 | 654.2 |
| .9 | 343.0 | 379.3 | 415.6 | 451.9 | 488.2 | 524.5 | 560.7 | 597.0 | 633.3 | 669.6 |
| 5.0 | 351.9 | 388.9 | 425.9 | 462.9 | 500.0 | 537.0 | 574.0 | 611.1 | 648.1 | 685.2 |
| 5.1 | 360.8 | 398.6 | 436.3 | 474.1 | 511.9 | 549.6 | 587.4 | 625.2 | 662.9 | 700.7 |
| .2 | 369.8 | 408.3 | 446.8 | 485.3 | 523.8 | 562.3 | 600.8 | 639.4 | 677.9 | 716.4 |
| .3 | 378.9 | 418.1 | 457.4 | 496.6 | 535.9 | 575.1 | 614.4 | 653.6 | 692.9 | 732.1 |
| .4 | 388.0 | 428.0 | 468.0 | 507.0 | 548.0 | 588.0 | 627.9 | 667.9 | 707.9 | 747.9 |
| .5 | 397.2 | 438.0 | 478.7 | 519.4 | 560.1 | 600.9 | 641.6 | 682.3 | 723.1 | 763.8 |
| .6 | 406.5 | 448.0 | 489.5 | 503.9 | 572.4 | 613.9 | 655.3 | 696.8 | 738.3 | 779.8 |
| .7 | 415.9 | 458.1 | 500.3 | 542.6 | 584.8 | 627.0 | 669.2 | 711.4 | 753.7 | 795.9 |
| .8 | 425.3 | 468.3 | 511.3 | 554.2 | 597.2 | 640.1 | 683.1 | 726.1 | 769.0 | 812.0 |
| .9 | 434.9 | 478.6 | 522.3 | 566.0 | 609.7 | 653.4 | 697.1 | 740.8 | 784.5 | 828.2 |
| 6.0 | 444.4 | 488.9 | 533.3 | 577.8 | 622.2 | 666.7 | 711.1 | 755.6 | 800.0 | 844.4 |

| Ht. in Ft. | Width of base (=2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 6.1 | 454.1 | 499.3 | 544.5 | 589.7 | 634.8 | 680.0 | 725.2 | 770.4 | 815.6 | 860.8 |
| .2 | 463.9 | 509.8 | 555.7 | 601.6 | 647.6 | 693.5 | 734.4 | 785.4 | 831.3 | 877.2 |
| .3 | 473.7 | 520.3 | 567.0 | 613.7 | 660.3 | 707.0 | 753.7 | 800.3 | 847.0 | 893.7 |
| .4 | 483.6 | 531.0 | 578.4 | 625.8 | 673.2 | 720.6 | 768.0 | 815.4 | 862.8 | 910.2 |
| .5 | 493.5 | 541.7 | 589.8 | 638.0 | 686.1 | 734.3 | 782.4 | 830.6 | 878.7 | 926.9 |
| .6 | 503.6 | 552.5 | 601.3 | 650.2 | 699.1 | 748.0 | 796.9 | 845.8 | 894.7 | 943.6 |
| .7 | 513.7 | 563.3 | 612.9 | 662.6 | 712.2 | 761.8 | 811.5 | 861.1 | 910.7 | 960.3 |
| .8 | 523.9 | 574.2 | 624.6 | 675.0 | 725.3 | 775.7 | 826.1 | 876.4 | 926.8 | 977.2 |
| .9 | 534.1 | 585.2 | 636.3 | 687.4 | 738.6 | 789.7 | 840.8 | 891.9 | 943.0 | 994.1 |
| 7.0 | 544.4 | 596.3 | 648.1 | 700.0 | 751.8 | 803.7 | 855.6 | 907.4 | 959.2 | 1011.1 |
| 7.1 | 554.9 | 607.4 | 660.0 | 712.6 | 765.2 | 817.8 | 870.4 | 923.0 | 975.6 | 1028.2 |
| .2 | 565.3 | 618.7 | 672.0 | 725.3 | 778.7 | 832.0 | 885.3 | 938.6 | 992.0 | 1045.3 |
| .3 | 575.9 | 630.0 | 684.0 | 738.1 | 792.2 | 846.2 | 900.3 | 954.4 | 1008.5 | 1062.6 |
| .4 | 586.5 | 641.3 | 696.1 | 751.0 | 805.8 | 860.6 | 915.4 | 970.2 | 1025.0 | 1079.8 |
| .5 | 597.2 | 652.8 | 708.3 | 763.9 | 819.5 | 875.0 | 930.6 | 986.1 | 1041.7 | 1097.2 |
| .6 | 608.0 | 664.3 | 720.6 | 776.9 | 833.2 | 889.5 | 945.8 | 1002.1 | 1058.4 | 1114.7 |
| .7 | 618.9 | 675.9 | 732.9 | 790.0 | 847.0 | 904.1 | 961.1 | 1018.1 | 1075.2 | 1132.2 |
| .8 | 629.8 | 686.6 | 744.3 | 801.1 | 859.9 | 917.7 | 975.4 | 1033.2 | 1091.0 | 1148.8 |
| .9 | 640.8 | 699.3 | 757.8 | 816.3 | 874.8 | 933.3 | 991.8 | 1050.4 | 1108.9 | 1167.4 |
| 8.0 | 651.9 | 711.1 | 770.4 | 829.6 | 888.9 | 948.2 | 1007.4 | 1066.7 | 1125.9 | 1185.2 |
| 8.1 | 663.0 | 723.0 | 783.0 | 843.0 | 903.0 | 963.0 | 1023.0 | 1083.0 | 1143.0 | 1203.0 |
| .2 | 674.2 | 735.0 | 795.7 | 856.4 | 917.2 | 977.9 | 1038.7 | 1099.4 | 1160.1 | 1220.9 |
| .3 | 685.5 | 747.0 | 808.5 | 870.0 | 931.4 | 992.9 | 1054.4 | 1115.9 | 1177.4 | 1238.8 |
| .4 | 696.9 | 759.1 | 821.3 | 883.5 | 945.8 | 1008.0 | 1070.2 | 1132.4 | 1194.7 | 1256.9 |
| .5 | 708.3 | 771.3 | 834.3 | 897.2 | 960.2 | 1023.1 | 1086.1 | 1149.1 | 1212.0 | 1275.0 |
| .6 | 719.9 | 783.6 | 847.3 | 911.0 | 974.7 | 1038.4 | 1102.1 | 1165.8 | 1229.5 | 1293.2 |
| .7 | 731.4 | 795.9 | 860.3 | 924.8 | 989.2 | 1053.6 | 1118.1 | 1182.5 | 1247.0 | 1311.4 |
| .8 | 743.1 | 808.3 | 873.5 | 938.7 | 1003.8 | 1069.0 | 1134.2 | 1199.4 | 1264.6 | 1329.7 |
| .9 | 754.9 | 820.8 | 886.7 | 952.6 | 1018.5 | 1084.5 | 1150.4 | 1216.3 | 1282.2 | 1348.1 |
| 9.0 | 766.7 | 833.3 | 900.0 | 966.7 | 1033.3 | 1100.0 | 1166.7 | 1233.3 | 1300.0 | 1366.7 |
| 9.1 | 778.6 | 846.0 | 913.4 | 980.8 | 1048.2 | 1115.6 | 1183.0 | 1250.4 | 1317.8 | 1385.3 |
| .2 | 790.5 | 858.7 | 926.8 | 995.0 | 1063.1 | 1131.3 | 1199.4 | 1267.6 | 1335.7 | 1403.9 |
| .3 | 802.6 | 871.5 | 940.3 | 1009.2 | 1078.1 | 1147.0 | 1215.9 | 1284.8 | 1353.7 | 1422.6 |
| .4 | 814.7 | 884.3 | 953.9 | 1023.6 | 1093.2 | 1162.8 | 1232.5 | 1302.1 | 1371.7 | 1441.3 |
| .5 | 826.9 | 897.2 | 967.6 | 1038.0 | 1108.3 | 1178.7 | 1249.1 | 1319.4 | 1389.8 | 1460.2 |
| .6 | 839.1 | 910.2 | 981.3 | 1052.4 | 1123.6 | 1194.7 | 1265.8 | 1336.9 | 1408.0 | 1479.1 |
| .7 | 851.4 | 923.3 | 995.1 | 1067.0 | 1138.8 | 1210.7 | 1282.5 | 1354.4 | 1426.2 | 1498.1 |
| .8 | 863.9 | 936.4 | 1009.0 | 1081.6 | 1154.2 | 1226.8 | 1299.4 | 1372.0 | 1444.6 | 1517.2 |
| .9 | 876.3 | 949.7 | 1022.1 | 1096.3 | 1169.7 | 1243.0 | 1316.3 | 1389.6 | 1463.0 | 1536.3 |
| 10.0 | 888.9 | 963.0 | 1037.0 | 1111.1 | 1185.2 | 1259.2 | 1333.3 | 1407.4 | 1481.5 | 1555.5 |
| 10.1 | 901.5 | 976.3 | 1051.2 | 1126.0 | 1200.8 | 1275.6 | 1350.4 | 1425.3 | 1500.1 | 1574.9 |
| .2 | 914.2 | 989.8 | 1065.3 | 1140.9 | 1216.5 | 1292.0 | 1367.6 | 1443.1 | 1518.7 | 1594.3 |
| .3 | 927.0 | 1003.3 | 1079.6 | 1155.9 | 1232.2 | 1308.5 | 1484.8 | 1461.1 | 1537.4 | 1613.7 |
| .4 | 939.9 | 1016.9 | 1093.9 | 1171.0 | 1248.0 | 1325.1 | 1402.1 | 1479.1 | 1556.2 | 1633.2 |
| .5 | 952.8 | 1030.6 | 1108.3 | 1186.1 | 1263.9 | 1341.7 | 1419.4 | 1497.2 | 1575.0 | 1652.8 |
| .6 | 965.8 | 1044.3 | 1122.8 | 1201.3 | 1279.9 | 1358.4 | 1436.9 | 1515.4 | 1593.9 | 1672.5 |
| .7 | 978.9 | 1058.1 | 1137.4 | 1216.6 | 1295.9 | 1375.2 | 1454.4 | 1533.7 | 1612.9 | 1692.2 |
| .8 | 992.0 | 1072.0 | 1152.0 | 1232.0 | 1312.0 | 1392.0 | 1472.0 | 1552.0 | 1632.0 | 1712.0 |
| .9 | 1005.2 | 1086.0 | 1166.7 | 1247.4 | 1328.2 | 1408.9 | 1489.7 | 1570.4 | 1651.1 | 1731.9 |
| 11.0 | 1018.5 | 1100.0 | 1181.5 | 1263.0 | 1344.4 | 1425.9 | 1507.4 | 1588.9 | 1670.4 | 1751.8 |
| 11.1 | 1031.9 | 1114.1 | 1196.3 | 1278.6 | 1360.8 | 1443.0 | 1525.2 | 1607.4 | 1689.7 | 1771.9 |
| .2 | 1045.3 | 1122.3 | 1211.3 | 1294.2 | 1377.2 | 1460.1 | 1543.1 | 1626.1 | 1709.0 | 1792.0 |
| .3 | 1058.9 | 1142.6 | 1226.3 | 1310.0 | 1393.7 | 1477.4 | 1561.1 | 1644.8 | 1728.5 | 1812.2 |
| .4 | 1072.4 | 1156.9 | 1241.3 | 1325.8 | 1410.2 | 1495.0 | 1579.1 | 1663.5 | 1748.0 | 1832.4 |
| .5 | 1086.1 | 1171.3 | 1256.5 | 1341.7 | 1426.8 | 1512.0 | 1597.2 | 1682.4 | 1767.6 | 1852.8 |
| .6 | 1099.9 | 1185.8 | 1271.7 | 1357.6 | 1443.6 | 1529.5 | 1615.4 | 1701.4 | 1787.3 | 1873.2 |
| .7 | 1113.7 | 1200.3 | 1287.0 | 1373.7 | 1460.3 | 1547.0 | 1633.7 | 1720.3 | 1807.0 | 1993.7 |
| .8 | 1127.6 | 1215.0 | 1302.4 | 1390.0 | 1477.2 | 1564.6 | 1652.0 | 1739.4 | 1826.8 | 1914.3 |
| .9 | 1141.5 | 1229.7 | 1317.8 | 1406.0 | 1494.1 | 1582.3 | 1670.4 | 1758.6 | 1846.7 | 1934.9 |
| 12.0 | 1155.6 | 1244.5 | 1333.3 | 1422.2 | 1511.1 | 1600.0 | 1688.9 | 1777.7 | 1866.7 | 1955.6 |

| Ht. in Ft. | Width of base ( =2$b$) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 12.1 | 1169.7 | 1259.3 | 1348.9 | 1438.6 | 1528.2 | 1617.8 | 1707.5 | 1797.1 | 1886.7 | 1976.3 |
| .1 | 1183.9 | 1274.2 | 1364.6 | 1455.0 | 1545.3 | 1635.7 | 1726.1 | 1816.4 | 1906.8 | 1997.2 |
| .3 | 1198.1 | 1289.2 | 1380.3 | 1471.4 | 1562.6 | 1653.7 | 1744.8 | 1835.9 | 1927.0 | 2018.1 |
| .4 | 1212.4 | 1304.3 | 1396.1 | 1488.0 | 1579.8 | 1671.7 | 1763.5 | 1855.4 | 1947.2 | 2039.1 |
| .5 | 1226.9 | 1319.4 | 1412.0 | 1504.6 | 1597.2 | 1689.8 | 1782.4 | 1875.0 | 1967.6 | 2060.2 |
| .6 | 1241.3 | 1334.7 | 1428.0 | 1521.3 | 1614.7 | 1708.0 | 1801.3 | 1894.6 | 1988.0 | 2081.3 |
| .7 | 1255.9 | 1350.0 | 1444.0 | 1538.1 | 1632.2 | 1726.2 | 1820.3 | 1914.4 | 2008.5 | 2102.5 |
| .8 | 1270.5 | 1365.3 | 1460.1 | 1555.0 | 1649.8 | 1744.6 | 1839.4 | 1934.2 | 2029.0 | 2123.8 |
| .9 | 1285.2 | 1380.8 | 1476.3 | 1571.9 | 1667.5 | 1763.0 | 1858.6 | 1954.1 | 2049.7 | 2145.2 |
| 13.0 | 1300.0 | 1396.3 | 1492.6 | 1588.9 | 1685.2 | 1781.5 | 1877.8 | 1974.1 | 2070.4 | 2166.7 |
| **13.1** | 1314.9 | 1411.9 | 1508.9 | 1606.0 | 1703.0 | 1800.1 | 1897.1 | 1994.1 | 2091.2 | 2188.2 |
| .2 | 1329.8 | 1427.6 | 1525.3 | 1623.1 | 1720.9 | 1818.7 | 1916.4 | 2014.2 | 2112.0 | 2209.8 |
| .3 | 1344.8 | 1443.3 | 1541.8 | 1640.4 | 1738.9 | 1837.4 | 1935.9 | 2034.4 | 2133.0 | 2231.5 |
| .4 | 1359.9 | 1459.1 | 1558.4 | 1657.6 | 1756.9 | 1856.2 | 1955.4 | 2054.7 | 2153.9 | 2253.2 |
| .5 | 1375.0 | 1475.0 | 1575.0 | 1675.0 | 1775.0 | 1875.0 | 1975.0 | 2075.0 | 2175.0 | 2275.0 |
| .6 | 1390.2 | 1491.0 | 1591.7 | 1692.4 | 1793.2 | 1893.9 | 1994.7 | 2095.4 | 2196.1 | 2296.9 |
| .7 | 1405.5 | 1507.0 | 1608.5 | 1710.0 | 1811.4 | 1912.9 | 2014.4 | 2115.9 | 2217.4 | 2318.9 |
| .8 | 1420.9 | 1523.1 | 1625.3 | 1727.6 | 1829.8 | 1932.0 | 2034.2 | 2136.4 | 2238.7 | 2340.9 |
| .9 | 1436.3 | 1539.3 | 1642.3 | 1745.2 | 1848.2 | 1951.1 | 2054.1 | 2157.1 | 2260.0 | 2363.0 |
| 14.0 | 1451.9 | 1555.6 | 1659.3 | 1763.0 | 1866.7 | 1970.4 | 2074.1 | 2177.8 | 2281.5 | 2385.2 |
| 14.1 | 1467.4 | 1571.9 | 1676.3 | 1780.8 | 1885.2 | 1989.6 | 2094.1 | 2198.5 | 2303.0 | 2407.4 |
| .2 | 1483.1 | 1588.3 | 1693.5 | 1798.7 | 1903.9 | 2009.1 | 2114.3 | 2219.4 | 2324.6 | 2429.8 |
| .3 | 1498.9 | 1604.8 | 1710.7 | 1816.6 | 1922.6 | 2028.5 | 2134.4 | 2240.4 | 2346.3 | 2452.2 |
| .4 | 1514.7 | 1621.3 | 1728.0 | 1834.7 | 1941.3 | 2048.0 | 2154.7 | 2261.3 | 2368.0 | 2474.7 |
| .5 | 1530.6 | 1638.0 | 1745.4 | 1852.8 | 1960.2 | 2067.6 | 2175.0 | 2282.4 | 2389.8 | 2497.3 |
| .6 | 1546.5 | 1654.7 | 1762.8 | 1871.0 | 1979.1 | 2087.3 | 2195.4 | 2303.6 | 2411.7 | 2519.9 |
| .7 | 1562.6 | 1671.5 | 1780.3 | 1889.2 | 1998.1 | 2107.0 | 2215.9 | 2324.8 | 2433.7 | 2542.6 |
| .8 | 1578.7 | 1688.3 | 1797.9 | 1907.6 | 2017.2 | 2126.8 | 2236.5 | 2346.1 | 2455.7 | 2565.3 |
| .9 | 1594.9 | 1705.2 | 1815.6 | 1926.0 | 2036.3 | 2146.7 | 2257.1 | 2367.4 | 2477.8 | 2588.2 |
| 15.0 | 1611.1 | 1722.2 | 1833.3 | 1944.4 | 2055.6 | 2166.7 | 2277.8 | 2388.9 | 2500.0 | 2611.1 |
| 16 | 1778 | 1896 | 2015 | 2133 | 2252 | 2370 | 2489 | 2607 | 2726 | 2844 |
| 17 | 1952 | 2078 | 2204 | 2330 | 2456 | 2581 | 2707 | 2833 | 2959 | 3085 |
| 18 | 2133 | 2267 | 2400 | 2533 | 2667 | 2800 | 2933 | 3067 | 3200 | 3333 |
| 19 | 2322 | 2463 | 2604 | 2744 | 2885 | 3026 | 3167 | 3307 | 3448 | 3589 |
| 20 | 2519 | 2667 | 2815 | 2963 | 3111 | 3259 | 3407 | 3556 | 3704 | 3852 |
| 21 | 2722 | 2878 | 3033 | 3189 | 3344 | 3500 | 3656 | 3811 | 3967 | 4122 |
| 22 | 2933 | 3096 | 3259 | 3422 | 3585 | 3748 | 3911 | 4074 | 4237 | 4444 |
| 23 | 3152 | 3322 | 3493 | 3663 | 3833 | 4004 | 4174 | 4344 | 4515 | 4685 |
| 24 | 3378 | 3556 | 3733 | 3911 | 4089 | 4267 | 4444 | 4622 | 4800 | 4978 |
| 25 | 3611 | 3796 | 3981 | 4167 | 4352 | 4537 | 4722 | 4907 | 5093 | 5278 |
| 26 | 3852 | 4044 | 4237 | 4430 | 4622 | 4815 | 5007 | 5200 | 5393 | 5585 |
| 27 | 4100 | 4300 | 4500 | 4700 | 4900 | 5100 | 5300 | 5500 | 5700 | 5900 |
| 28 | 4356 | 4563 | 4770 | 4978 | 5185 | 5393 | 5600 | 5807 | 6015 | 6222 |
| 29 | 4619 | 4833 | 5048 | 5263 | 5478 | 5693 | 5907 | 6122 | 6337 | 6552 |
| 30 | 4889 | 5111 | 5333 | 5556 | 5778 | 6000 | 6222 | 6444 | 6667 | 6889 |
| 31 | 5167 | 5396 | 5626 | 5856 | 6085 | 6315 | 6544 | 6774 | 7004 | 7233 |
| 32 | 5452 | 5689 | 5926 | 6163 | 6400 | 6637 | 6874 | 7111 | 7348 | 7585 |
| 33 | 5744 | 5989 | 6233 | 6478 | 6722 | 6967 | 7211 | 7456 | 7700 | 7944 |
| 34 | 6044 | 6296 | 6548 | 6800 | 7052 | 7304 | 7556 | 7807 | 8059 | 8311 |
| 35 | 6352 | 6611 | 6870 | 7130 | 7389 | 7648 | 7907 | 8167 | 8426 | 8685 |
| 36 | 6667 | 6933 | 7200 | 7467 | 7733 | 8000 | 8267 | 8533 | 8800 | 9067 |
| 37 | 6989 | 7263 | 7537 | 7811 | 8085 | 8359 | 8633 | 8907 | 9181 | 9456 |
| 38 | 7319 | 7600 | 7881 | 8163 | 8444 | 8726 | 9007 | 9289 | 9570 | 9852 |
| 39 | 7656 | 7944 | 8233 | 8522 | 8811 | 9100 | 9389 | 9678 | 9967 | 10256 |
| 40 | 8000 | 8296 | 8593 | 8889 | 9185 | 9481 | 9778 | 10074 | 10370 | 10667 |
| 41 | 8352 | 8656 | 8954 | 9263 | 9567 | 9870 | 10174 | 10478 | 10781 | 11085 |
| 42 | 8711 | 9022 | 9333 | 9644 | 9956 | 10267 | 10578 | 10889 | 11200 | 11511 |
| 43 | 9078 | 9396 | 9715 | 10033 | 10352 | 10670 | 10989 | 11307 | 11626 | 11944 |
| 44 | 9452 | 9778 | 10104 | 10430 | 10756 | 11081 | 11407 | 11733 | 12059 | 12385 |
| 45 | 9833 | 10167 | 10500 | 10833 | 11167 | 11500 | 11833 | 12167 | 12500 | 12833 |

## TABLE XIX.—CU. YDS. PER 100 FT. SLOPES 1½ TO 1.

| Ht. in Ft. | Width of base (=2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 0.1 | 5.2 | 6.0 | 6.8 | 7.5 | 8.3 | 9.0 | 9.7 | 10.5 | 11.2 | 11.9 |
| .2 | 10.6 | 12.1 | 13.6 | 15.0 | 16.5 | 18.0 | 19.5 | 21.0 | 22.4 | 23.9 |
| .3 | 16.16 | 18.3 | 20.5 | 22.7 | 24.9 | 27.2 | 29.4 | 31.6 | 33.8 | 36.1 |
| .4 | 21.63 | 24.6 | 27.6 | 30.5 | 33.5 | 36.4 | 39.4 | 42.4 | 45.3 | 48.3 |
| .5 | 27.32 | 31.0 | 34.7 | 38.4 | 42.1 | 45.8 | 49.5 | 53.2 | 56.9 | 60.6 |
| .6 | 33.11 | 37.6 | 42.0 | 46.4 | 50.9 | 55.3 | 59.8 | 64.2 | 68.7 | 73.1 |
| .7 | 39.02 | 44.2 | 49.4 | 54.6 | 59.8 | 65.0 | 70.2 | 75.4 | 80.5 | 85.7 |
| .8 | 45.04 | 51.0 | 56.9 | 62.8 | 68.8 | 74.7 | 80.6 | 86.6 | 92.5 | 98.4 |
| .9 | 51.17 | 57.8 | 64.5 | 71.2 | 77.8 | 84.5 | 91.2 | 97.8 | 104.5 | 111.2 |
| 1.0 | 57.41 | 64.8 | 72.2 | 79.6 | 87.1 | 94.5 | 101.9 | 109.3 | 116.7 | 124.1 |
| 1.1 | 63.76 | 71.9 | 80.1 | 88.2 | 96.4 | 104.5 | 112.7 | 120.8 | 129.0 | 137.1 |
| .2 | 70.22 | 79.1 | 88.0 | 96.9 | 105.8 | 114.7 | 123.6 | 132.5 | 141.3 | 150.2 |
| .3 | 76.80 | 86.4 | 96.1 | 105.7 | 115.3 | 125.0 | 134.6 | 144.2 | 153.8 | 163.5 |
| .4 | 83.48 | 93.9 | 104.2 | 114.6 | 125.0 | 135.3 | 145.7 | 156.1 | 166.4 | 176.8 |
| .5 | 90.28 | 101.4 | 112.5 | 123.6 | 134.7 | 145.8 | 156.9 | 168.1 | 179.2 | 190.3 |
| .6 | 97.19 | 109.0 | 120.9 | 132.7 | 144.6 | 156.4 | 168.3 | 180 1 | 192.0 | 203.9 |
| .7 | 104.20 | 116.8 | 129.4 | 142.0 | 154.6 | 167.2 | 179.7 | 192.3 | 204.9 | 217.5 |
| .8 | 111.33 | 124.7 | 138.0 | 151.3 | 164.7 | 178.0 | 191.3 | 204.7 | 218.0 | 231.3 |
| .9 | 118.57 | 132.6 | 146.7 | 160.8 | 174.9 | 188.2 | 203.0 | 217.1 | 231.1 | 245.2 |
| 2.0 | 125.93 | 140.7 | 155.6 | 170.4 | 185.2 | 200.0 | 214.8 | 229.6 | 244.4 | 259.2 |
| 2.1 | 133.39 | 148.9 | 164.5 | 180.0 | 195.6 | 211.1 | 226.7 | 242.2 | 257.8 | 273.3 |
| .2 | 140.96 | 157.3 | 173.5 | 189.8 | 206.1 | 222.4 | 238.7 | 255.0 | 271.3 | 287.6 |
| .3 | 148.65 | 165.7 | 182.7 | 199.7 | 216.8 | 233.8 | 250.8 | 267.9 | 284.9 | 301.9 |
| .4 | 156.44 | 174.2 | 192.0 | 209.8 | 227.5 | 245.3 | 263.1 | 280.8 | 298.6 | 316.4 |
| .5 | 164.35 | 182.9 | 201.4 | 219.9 | 238.4 | 256.9 | 275.4 | 293.9 | 312.4 | 330.9 |
| .6 | 172.37 | 191.6 | 210.9 | 230.2 | 249.4 | 268.7 | 287.9 | 307.2 | 326.5 | 345.7 |
| .7 | 180.50 | 200.5 | 220.5 | 240.5 | 260.5 | 280.5 | 300.5 | 320.5 | 340.5 | 360.5 |
| .8 | 188.74 | 209.5 | 230.2 | 251.0 | 271.7 | 292.4 | 313.2 | 333.9 | 354.7 | 375.4 |
| .9 | 197.09 | 218.6 | 240.1 | 261.5 | 283.0 | 304.5 | 326.0 | 347.5 | 368.9 | 390.4 |
| 3.0 | 205.56 | 227.8 | 250.0 | 272.2 | 294.4 | 316.7 | 338.9 | 361.1 | 383.3 | 405.6 |
| 3.1 | 214.13 | 237.1 | 260.1 | 283.0 | 306.0 | 328.9 | 351.9 | 374.9 | 397.8 | 420.8 |
| .2 | 222.81 | 246.5 | 270.2 | 293.9 | 317.6 | 341.3 | 365.0 | 388.7 | 412.4 | 436.1 |
| .3 | 231.61 | 256.1 | 280.5 | 304.9 | 329.4 | 353.8 | 378.3 | 402.7 | 427.2 | 451.6 |
| .4 | 240.52 | 265.7 | 290.9 | 316.1 | 341.2 | 366.4 | 391.6 | 416.8 | 442.0 | 467.1 |
| .5 | 249.54 | 275.5 | 301.4 | 327.3 | 353.2 | 379.1 | 405.1 | 431.0 | 456.9 | 482.8 |
| .6 | 258.67 | 285.3 | 312.0 | 338.7 | 365.3 | 392.0 | 418.6 | 445.3 | 472.0 | 498.7 |
| .7 | 267.91 | 295.3 | 322.7 | 350.1 | 377.5 | 404.9 | 432.3 | 459.7 | 487.1 | 514.5 |
| .8 | 277.26 | 305.4 | 333.5 | 361.7 | 389.8 | 418.0 | 446.1 | 474.3 | 502.4 | 530.6 |
| .9 | 286.72 | 315.6 | 344.5 | 373.4 | 402.2 | 431.1 | 460.0 | 488.9 | 517.8 | 546.7 |
| 4.0 | 296.30 | 325.9 | 355.5 | 385.2 | 414.8 | 444.4 | 474.0 | 503.6 | 533.3 | 562.9 |
| 4.1 | 305.98 | 336.3 | 366.7 | 397.1 | 427.4 | 457.8 | 488.1 | 518.5 | 548.9 | 579.2 |
| .2 | 315.78 | 346.9 | 378.0 | 409.1 | 440.2 | 471.3 | 502.4 | 533.5 | 564.6 | 595.7 |
| .3 | 325.69 | 357.5 | 389.4 | 421.2 | 453.1 | 484.9 | 516.8 | 548.6 | 580.5 | 612.5 |
| .4 | 335.70 | 368.3 | 400.9 | 433.5 | 466.1 | 498.7 | 531.2 | 563.8 | 596.4 | 629.0 |
| .5 | 345.83 | 379.2 | 412.5 | 445.8 | 479.2 | 512.5 | 545.8 | 579.2 | 612.5 | 645.8 |
| .6 | 356.07 | 390.1 | 424.2 | 458.3 | 492.4 | 526.4 | 560.5 | 594.6 | 628.6 | 662.7 |
| .7 | 366.43 | 401.2 | 436.1 | 470.9 | 505.7 | 540.5 | 575.3 | 610.1 | 644.9 | 679.8 |
| .8 | 376.89 | 412.4 | 448.0 | 483.6 | 519.1 | 554.7 | 590.2 | 625.7 | 661.3 | 696.9 |
| .9 | 387.46 | 423.8 | 460.0 | 496.3 | 532.6 | 568.9 | 605.2 | 641.5 | 677.8 | 714.1 |
| 5.0 | 398.15 | 435.2 | 472.2 | 509.3 | 546.3 | 583.3 | 620.3 | 657.4 | 694.4 | 731.4 |
| 5.1 | 408.9 | 446.7 | 484.5 | 522.3 | 560.0 | 597.8 | 635.6 | 673.3 | 711.1 | 748.9 |
| .2 | 419.9 | 458.4 | 496.9 | 535.4 | 573.9 | 612.4 | 650.9 | 689.4 | 727.9 | 766.4 |
| .3 | 430.9 | 470.1 | 509.4 | 548.6 | 587.9 | 627.1 | 666.4 | 705.6 | 744.9 | 784.1 |
| .4 | 442.0 | 482.0 | 522.0 | 562.0 | 602.0 | 642.0 | 681.9 | 721.9 | 761.9 | 801.9 |
| .5 | 453.2 | 494.0 | 534.7 | 575.4 | 616.2 | 656.9 | 597.6 | 738.4 | 779.1 | 819.8 |
| .6 | 464.6 | 506.1 | 547.5 | 589.0 | 630.5 | 671.9 | 713.4 | 754.9 | 796.4 | 837.8 |
| .7 | 476.1 | 518.3 | 560.5 | 602.7 | 644.9 | 687.2 | 729.4 | 771.6 | 813.8 | 856.0 |
| .8 | 487.6 | 530.6 | 573.6 | 616.5 | 659.5 | 702.4 | 745.4 | 788.4 | 831.3 | 874.3 |
| .9 | 499.3 | 543.0 | 586.7 | 630.4 | 674.1 | 717.8 | 761.5 | 805.2 | 848.9 | 892.6 |
| 6.0 | 511.1 | 555.6 | 600.0 | 644.4 | 688.9 | 733.3 | 777.8 | 822.2 | 866.7 | 911.1 |

| Ht. in Ft. | Width of base ( = 2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| **6.1** | 523.0 | 568.2 | 613.4 | 658.6 | 703.7 | 748.9 | 794.1 | 839.3 | 884.5 | 829.6 |
| .2 | 535.0 | 581.0 | 626.9 | 672.8 | 718.8 | 764.7 | 810.6 | 856.6 | 902.5 | 948.4 |
| .3 | 547.2 | 593.8 | 640.5 | 687.2 | 733.8 | 780.5 | 827.2 | 873.8 | 920.5 | 967.2 |
| .4 | 559.4 | 606.8 | 654.2 | 701.6 | 749.1 | 796.5 | 843.9 | 891.3 | 938.7 | 986.1 |
| .5 | 571.8 | 619.9 | 668.1 | 716.2 | 764.4 | 812.5 | 860.7 | 908.8 | 857.0 | 1005.1 |
| .6 | 584.2 | 633.1 | 682.0 | 730.9 | 779.8 | 828.7 | 877.6 | 926.5 | 975.3 | 1024.2 |
| .7 | 596.8 | 646.4 | 696.1 | 745.7 | 795.3 | 845.0 | 894.6 | 944.2 | 993.8 | 1043.5 |
| .8 | 609.5 | 659.9 | 710.2 | 760.6 | 811.0 | 861.3 | 911.7 | 962.1 | 1015.1 | 1065.5 |
| .9 | 622.3 | 673.4 | 724.5 | 775.6 | 826.7 | 877.8 | 928.9 | 980.1 | 1031.2 | 1082.3 |
| **7.0** | 635.2 | 687.0 | 738.9 | 790.7 | 842.6 | 894.4 | 946.3 | 998.1 | 1050.0 | 1101.8 |
| **7.1** | 648.2 | 700.8 | 753.4 | 806.0 | 858.6 | 911.2 | 963.7 | 1016.3 | 1068.9 | 1121.5 |
| .2 | 661.3 | 714.7 | 768.0 | 821.3 | 874.7 | 928.0 | 981.3 | 1034.6 | 1088.0 | 1141.3 |
| .3 | 674.6 | 728.6 | 782.7 | 836.8 | 890.9 | 944.9 | 999.0 | 1053.1 | 1107.1 | 1161.2 |
| .4 | 687.9 | 742.7 | 797.6 | 852.4 | 907.2 | 962.0 | 1016.8 | 1071.6 | 1126.4 | 1181.2 |
| .5 | 701.4 | 757.0 | 812.5 | 868.1 | 923.6 | 979.2 | 1034.7 | 1090.3 | 1145.8 | 1201.4 |
| .6 | 715.0 | 771.3 | 827.6 | 883.9 | 940.2 | 996.5 | 1052.8 | 1109.1 | 1165.4 | 1221.7 |
| .7 | 728.7 | 785.7 | 842.7 | 899.8 | 956.8 | 1013.9 | 1070.9 | 1127.9 | 1185.0 | 1242.0 |
| .8 | 742.4 | 800.2 | 858.0 | 915.8 | 973.5 | 1031.3 | 1089.1 | 1146.9 | 1204.7 | 1262.4 |
| .9 | 756.4 | 914.9 | 873.4 | 931.9 | 990.4 | 1048.9 | 1107.4 | 1165.9 | 1224.4 | 1282.9 |
| **8.0** | 770.4 | 829.6 | 888.9 | 948.2 | 1007.4 | 1066.7 | 1125.9 | 1185.2 | 1244.5 | 1303.7 |
| **8.1** | 784.5 | 844.5 | 904.5 | 964.5 | 1024.5 | 1084.5 | 1144.5 | 1204.5 | 1264.5 | 1324.5 |
| .2 | 798.7 | 859.5 | 920.2 | 981.0 | 1041.7 | 1102.4 | 1163.2 | 1223.9 | 1284.7 | 1345.4 |
| .3 | 813.1 | 874.6 | 936.1 | 997.5 | 1059.0 | 1120.5 | 1182.0 | 1243.5 | 1304.9 | 1366.4 |
| .4 | 827.6 | 889.8 | 952.0 | 1014.2 | 1076.4 | 1138.7 | 1200.9 | 1263.1 | 1325.3 | 1387.6 |
| .5 | 842.1 | 905.1 | 968.1 | 1031.0 | 1094.0 | 1156.9 | 1219.9 | 1282.9 | 1345.8 | 1408.8 |
| .6 | 856.8 | 920.5 | 984.2 | 1047.9 | 1111.6 | 1175.3 | 1239.0 | 1302.7 | 1366.4 | 1430.1 |
| .7 | 871.6 | 936.1 | 1000.5 | 1064.9 | 1129.4 | 1193.8 | 1258.3 | 1322.7 | 1387.2 | 1451.6 |
| .8 | 886.5 | 951.7 | 1016.9 | 1082.1 | 1147.2 | 1212.4 | 1277.6 | 1342.8 | 1408.0 | 1473.1 |
| .9 | 901.5 | 967.5 | 1033.4 | 1099.3 | 1165.2 | 1231.1 | 1297.1 | 1363.0 | 1428.9 | 1494.8 |
| **9.0** | 916.7 | 983.3 | 1050.0 | 1116.7 | 1183.3 | 1250.0 | 1316.7 | 1383.3 | 1450.0 | 1516.7 |
| **9.1** | 931.9 | 999.3 | 1066.7 | 1134.1 | 1201.6 | 1269.0 | 1336.4 | 1403.8 | 1471.2 | 1538.6 |
| .2 | 947.3 | 1015.4 | 1083.6 | 1151.7 | 1219.9 | 1288.0 | 1356.2 | 1424.3 | 1492.5 | 1560.6 |
| .3 | 962.7 | 1031.6 | 1100.5 | 1169.4 | 1238.3 | 1307.2 | 1376.1 | 1444.9 | 1513.8 | 1582.7 |
| .4 | 978.3 | 1047.9 | 1117.6 | 1187.2 | 1256.8 | 1326.5 | 1396.1 | 1465.7 | 1535.3 | 1605.0 |
| .5 | 994.0 | 1064.4 | 1134.7 | 1205.1 | 1275.5 | 1345.8 | 1416.2 | 1486.6 | 1556.9 | 1627.3 |
| .6 | 1009.8 | 1080.9 | 1152.0 | 1223.1 | 1294.2 | 1365.3 | 1436.4 | 1507.6 | 1578.7 | 1649.8 |
| .7 | 1025.7 | 1097.5 | 1169.4 | 1241.2 | 1313.1 | 1384.9 | 1456.8 | 1528.6 | 1600.5 | 1672.3 |
| .8 | 1041.7 | 1114.3 | 1186.9 | 1259.5 | 1332.1 | 1404.7 | 1477.2 | 1549.8 | 1622.4 | 1695.0 |
| .9 | 1057.8 | 1131.2 | 1204.5 | 1277.8 | 1351.1 | 1424.5 | 1497.8 | 1571.1 | 1644.5 | 1717.8 |
| **10.0** | 1074.1 | 1148.1 | 1222.2 | 1296.3 | 1370.4 | 1444.4 | 1518.5 | 1592.6 | 1666.6 | 1740.7 |
| **10.1** | 1090.4 | 1165.3 | 1240.1 | 1314.9 | 1389.7 | 1464.5 | 1539.4 | 1614.2 | 1689.0 | 1763.8 |
| .2 | 1106.9 | 1182.5 | 1258.0 | 1333.6 | 1409.1 | 1484.7 | 1560.2 | 1635.8 | 1711.3 | 1786.9 |
| .3 | 1123.5 | 1199.8 | 1276.1 | 1352.4 | 1428.7 | 1505.0 | 1581.3 | 1657.6 | 1733.9 | 1810.2 |
| .4 | 1140.2 | 1217.2 | 1294.2 | 1371.3 | 1448.3 | 1525.4 | 1602.4 | 1679.4 | 1756.5 | 1833.5 |
| .5 | 1156.9 | 1234.7 | 1312.5 | 1390.3 | 1468.1 | 1545.8 | 1623.6 | 1701.4 | 1779.2 | 1856.9 |
| .6 | 1173.9 | 1252.4 | 1330.9 | 1409.4 | 1487.9 | 1566.5 | 1645.0 | 1723.5 | 1802.0 | 1880.5 |
| .7 | 1190.9 | 1270.1 | 1349.4 | 1428.7 | 1507.9 | 1587.2 | 1666.4 | 1745.7 | 1825.0 | 1904.2 |
| .8 | 1208.0 | 1288.0 | 1368.0 | 1448.0 | 1528.0 | 1608.0 | 1688.0 | 1768.0 | 1848.0 | 1928.0 |
| .9 | 1225.2 | 1306.0 | 1386.7 | 1467.5 | 1548.2 | 1628.9 | 1709.7 | 1790.4 | 1871.2 | 1951.9 |
| **11.0** | 1242.6 | 1324.1 | 1405.6 | 1487.0 | 1568.5 | 1650.0 | 1731.5 | 1813.0 | 1894.4 | 1975.9 |
| **11.1** | 1260.1 | 1342.3 | 1424.5 | 1506.7 | 1588.9 | 1671.2 | 1753.4 | 1835.6 | 1917.8 | 2000.1 |
| .2 | 1277.6 | 1360.6 | 1443.6 | 1526.5 | 1609.5 | 1692.4 | 1775.4 | 1858.4 | 1947.6 | 2036.9 |
| .3 | 1295.3 | 1379.0 | 1462.7 | 1546.4 | 1630.1 | 1713.8 | 1797.5 | 1881.2 | 1964.9 | 2048.6 |
| .4 | 1313.1 | 1397.6 | 1482.0 | 1566.4 | 1650.9 | 1735.3 | 1819.8 | 1904.2 | 1988.7 | 2073.1 |
| .5 | 1331.0 | 1416.2 | 1501.4 | 1586.6 | 1671.7 | 1756.9 | 1842.1 | 1927.3 | 2012.5 | 2097.6 |
| .6 | 1349.0 | 1435.0 | 1520.9 | 1606.8 | 1692.8 | 1778.7 | 1864.6 | 1950.6 | 2036.5 | 2122.4 |
| .7 | 1367.2 | 1453.8 | 1540.5 | 1627.2 | 1713.8 | 1800.5 | 1887.2 | 1973.8 | 2060.5 | 2147.2 |
| .8 | 1385.4 | 1472.8 | 1560.2 | 1647.6 | 1735.1 | 1822.5 | 1909.9 | 1997.3 | 2084.7 | 2172.1 |
| .9 | 1403.8 | 1491.9 | 1580.1 | 1668.2 | 1756.4 | 1844.5 | 1932.7 | 2020.8 | 2109.0 | 2197.1 |
| **12.0** | 1422.2 | 1511.1 | 1600.0 | 1688.9 | 1777.8 | 1866.7 | 1955.6 | 2044.4 | 2133.3 | 2222.2 |

| Ht. in Ft. | Width of base (=2*b*) in feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** |
| 12.1 | 1440.8 | 1530.4 | 1620.1 | 1709.7 | 1799.3 | 1889.0 | 1978.6 | 2068.2 | 2157.8 | 2247.5 |
| .2 | 1459.5 | 1549.9 | 1640.2 | 1730.6 | 1821.0 | 1911.3 | 2001.7 | 2092.1 | 2182.4 | 2272.8 |
| .3 | 1478.3 | 1569.4 | 1660.5 | 1751.6 | 1842.7 | 1933.8 | 2024.9 | 2116.1 | 2207.2 | 2298.3 |
| .4 | 1497.2 | 1589.0 | 1680.9 | 1772.7 | 1864.6 | 1956.4 | 2048.3 | 2140.1 | 2232.0 | 2323.8 |
| .5 | 1516.2 | 1608.8 | 1701.4 | 1794.0 | 1886.6 | 1979.2 | 2071.7 | 2164.3 | 2256.9 | 2349.5 |
| .6 | 1535.3 | 1628.7 | 1722.0 | 1815.3 | 1908.7 | 2002.0 | 2095.3 | 2188.6 | 2282.0 | 2375.3 |
| .7 | 1554.6 | 1648.6 | 1742.7 | 1836.8 | 1930.9 | 2024.9 | 2119.0 | 2213.1 | 2307.1 | 2401.2 |
| .8 | 1573.9 | 1668.7 | 1763.5 | 1858.4 | 1953.2 | 2048.0 | 2142.8 | 2237.6 | 2332.4 | 2427.2 |
| .9 | 1593.4 | 1689.0 | 1784.5 | 1880.1 | 1975.6 | 2071.2 | 2166.7 | 2262.3 | 2357.8 | 2453.4 |
| 13.0 | 1613.0 | 1709.3 | 1805.6 | 1901.9 | 1998.2 | 2094.5 | 2190.8 | 2287.1 | 2383.4 | 2479.6 |
| 13.1 | 1632.6 | 1729.7 | 1826.7 | 1923.8 | 2020.8 | 2117.9 | 2214.9 | 2311.9 | 2409.0 | 2506.0 |
| .2 | 1652.4 | 1750.2 | 1848.0 | 1945.8 | 2043.6 | 2141.3 | 2239.1 | 2336.9 | 2434.7 | 2532.4 |
| .3 | 1672.4 | 1770.9 | 1869.4 | 1967.9 | 2066.4 | 2165.0 | 2263.5 | 2362.0 | 2460.5 | 2559.0 |
| .4 | 1692.4 | 1791.6 | 1890.9 | 1990.2 | 2039.4 | 2188.7 | 2287.9 | 2387.2 | 2486.5 | 2585.7 |
| .5 | 1712.5 | 1812.5 | 1912.5 | 2012.5 | 2112.5 | 2212.5 | 2312.5 | 2412.5 | 2512.5 | 2612.5 |
| .6 | 1732.7 | 1833.5 | 1934.2 | 2035.0 | 2135.7 | 2236.4 | 2337.2 | 2437.9 | 2538.7 | 2639.4 |
| .7 | 1753.1 | 1854.6 | 1956.1 | 2057.5 | 2159.0 | 2260.5 | 2362.0 | 2463.5 | 2564.9 | 2666.4 |
| .8 | 1773.6 | 1875.8 | 1978.0 | 2080.2 | 2182.4 | 2284.7 | 2386.9 | 2489.1 | 2591.3 | 2693.5 |
| .9 | 1794.1 | 1897.1 | 2000.1 | 2103.0 | 2206.0 | 2308.9 | 2411.9 | 2514.9 | 2617.8 | 2720.8 |
| 14.0 | 1814.8 | 1918.5 | 2022.2 | 2125.9 | 2229.6 | 2333.3 | 2437.0 | 2540.7 | 2644.4 | 2748.1 |
| 14.1 | 1835.6 | 1940.1 | 2044.5 | 2148.9 | 2253.4 | 2357.8 | 2462.3 | 2566.7 | 2671.1 | 2775.6 |
| .2 | 1856.5 | 1961.7 | 2066.9 | 2172.1 | 2277.3 | 2332.5 | 2487.7 | 2592.9 | 2698.0 | 2803.2 |
| .3 | 1877.5 | 1983.5 | 2089.4 | 2195.3 | 2301.3 | 2407.2 | 2513.1 | 2619.1 | 2725.0 | 2830.9 |
| .4 | 1898.7 | 2005.3 | 2112.0 | 2218.7 | 2325.3 | 2432.0 | 2538.7 | 2645.3 | 2752.0 | 2858.7 |
| .5 | 1919.9 | 2027.3 | 2134.7 | 2242.1 | 2349.6 | 2457.0 | 2564.4 | 2671.8 | 2779.2 | 2886.6 |
| .6 | 1941.3 | 2049.4 | 2157.6 | 2265.7 | 2373.9 | 2482.0 | 2590.2 | 2698.3 | 2806.5 | 2914.6 |
| .7 | 1962.7 | 2071.6 | 2180.5 | 2289.4 | 2398.3 | 2507.2 | 2616.1 | 2725.0 | 2833.8 | 2942.7 |
| .8 | 1984.3 | 2093.9 | 2203.6 | 2313.2 | 2422.8 | 2532.5 | 2642.1 | 2751.7 | 2861.3 | 2971.0 |
| .9 | 2006.0 | 2116.4 | 2226.7 | 2337.1 | 2447.5 | 2557.8 | 2668.2 | 2778.6 | 2888.9 | 2999.3 |
| 15.0 | 2027.8 | 2138.9 | 2250.0 | 2361.1 | 2472.2 | 2583.3 | 2694.4 | 2805.6 | 2916.7 | 3027.8 |
| 16 | 2252 | 2370 | 2489 | 2607 | 2726 | 2844 | 2963 | 3081 | 3200 | 3319 |
| 17 | 2487 | 2613 | 2739 | 2365 | 2991 | 3117 | 3243 | 3369 | 3494 | 3620 |
| 18 | 2733 | 2867 | 3000 | 3133 | 3267 | 3400 | 3533 | 3667 | 3800 | 3933 |
| 19 | 2991 | 3131 | 3272 | 3413 | 3554 | 3694 | 3835 | 3976 | 4117 | 4257 |
| 20 | 3259 | 3407 | 3556 | 3704 | 3852 | 4000 | 4148 | 4296 | 4444 | 4592 |
| 21 | 3539 | 3694 | 3850 | 4005 | 4161 | 4317 | 4472 | 4628 | 4783 | 4939 |
| 22 | 3830 | 3993 | 4156 | 4318 | 4481 | 4644 | 4807 | 4970 | 5133 | 5296 |
| 23 | 4133 | 4302 | 4472 | 4642 | 4813 | 4983 | 5154 | 5324 | 5494 | 5665 |
| 24 | 4444 | 4622 | 4800 | 4978 | 5156 | 5333 | 5511 | 5689 | 5867 | 6044 |
| 25 | 4769 | 4954 | 5139 | 5324 | 5509 | 5694 | 5880 | 6065 | 6250 | 6435 |
| 26 | 5104 | 5296 | 5489 | 5681 | 5874 | 6067 | 6259 | 6452 | 0644 | 6837 |
| 27 | 5450 | 5650 | 5850 | 6050 | 6250 | 6450 | 6650 | 6850 | 7050 | 7250 |
| 28 | 5807 | 6015 | 6222 | 6430 | 6637 | 6844 | 7052 | 7259 | 7467 | 7674 |
| 29 | 6176 | 6391 | 6606 | 6820 | 7035 | 7250 | 7465 | 7680 | 7894 | 8109 |
| 30 | 6556 | 6778 | 7000 | 7222 | 7444 | 7667 | 7889 | 8111 | 8333 | 8555 |
| 31 | 6946 | 7176 | 7406 | 7635 | 7865 | 8094 | 8324 | 8554 | 8783 | 9013 |
| 32 | 7348 | 7585 | 7822 | 8059 | 8296 | 8533 | 8770 | 9007 | 9244 | 9482 |
| 33 | 7761 | 8006 | 8250 | 8494 | 8739 | 8983 | 9228 | 9472 | 9717 | 9962 |
| 34 | 8185 | 8437 | 8689 | 8941 | 9193 | 9444 | 9696 | 9948 | 10200 | 10452 |
| 35 | 8620 | 8880 | 9139 | 9398 | 9657 | 9917 | 10176 | 10435 | 10694 | 10954 |
| 36 | 9067 | 9333 | 9600 | 9867 | 10133 | 10300 | 10467 | 10933 | 11200 | 11467 |
| 37 | 9524 | 9798 | 10072 | 10346 | 10620 | 10895 | 11169 | 11443 | 11717 | 11991 |
| 38 | 9993 | 10274 | 10556 | 10337 | 11119 | 11400 | 11681 | 11963 | 12244 | 12526 |
| 39 | 10472 | 10761 | 11050 | 11339 | 11628 | 11917 | 12206 | 12494 | 12783 | 13072 |
| 40 | 10963 | 11259 | 11556 | 11852 | 12148 | 12444 | 12741 | 13037 | 13333 | 13630 |
| 41 | 11465 | 11769 | 12072 | 12376 | 12680 | 12983 | 13287 | 13591 | 13894 | 14198 |
| 42 | 11978 | 12289 | 12600 | 12911 | 13223 | 13534 | 13845 | 14156 | 14467 | 14778 |
| 43 | 12502 | 12820 | 13139 | 13457 | 13776 | 14094 | 14413 | 14731 | 15050 | 15369 |
| 44 | 13037 | 13363 | 13689 | 14015 | 14341 | 14667 | 14993 | 15319 | 15644 | 15970 |
| 45 | 13583 | 13917 | 14250 | 14583 | 14917 | 15250 | 15583 | 15917 | 16250 | 16583 |

| Depth | Base 12 | Base 14 | Base 16 | Base 18 | Base 20 | Base 28 | Base 30 | Base 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 52 | 59 | 67 | 74 | 81 | 111 | 119 | 126 |
| 2 | 119 | 133 | 148 | 163 | 178 | 237 | 252 | 267 |
| 3 | 200 | 222 | 244 | 267 | 289 | 378 | 400 | 422 |
| 4 | 296 | 326 | 356 | 385 | 415 | 533 | 563 | 593 |
| 5 | 407 | 444 | 481 | 519 | 556 | 704 | 741 | 778 |
| 6 | 533 | 578 | 622 | 667 | 711 | 889 | 933 | 978 |
| 7 | 674 | 726 | 778 | 830 | 881 | 1089 | 1141 | 1193 |
| 8 | 830 | 889 | 948 | 1007 | 1067 | 1304 | 1363 | 1422 |
| 9 | 1000 | 1067 | 1133 | 1200 | 1267 | 1533 | 1600 | 1667 |
| 10 | 1185 | 1259 | 1333 | 1407 | 1481 | 1778 | 1852 | 1926 |
| 11 | 1385 | 1467 | 1548 | 1630 | 1711 | 2037 | 2119 | 2200 |
| 12 | 1600 | 1689 | 1778 | 1867 | 1956 | 2311 | 2400 | 2489 |
| 13 | 1830 | 1926 | 2022 | 2119 | 2215 | 2600 | 2696 | 2793 |
| 14 | 2074 | 2178 | 2281 | 2385 | 2489 | 2904 | 3007 | 3111. |
| 15 | 2333 | 2444 | 2556 | 2667 | 2778 | 3222 | 3333 | 3444 |
| 16 | 2607 | 2726 | 2844 | 2963 | 3081 | 3556 | 3674 | 3793 |
| 17 | 2896 | 3022 | 3148 | 3274 | 3400 | 3904 | 4030 | 4156 |
| 18 | 3200 | 3333 | 3467 | 3600 | 3733 | 4267 | 4400 | 4533 |
| 19 | 3519 | 3659 | 3800 | 3941 | 4081 | 4644 | 4785 | 4926 |
| 20 | 3852 | 4000 | 4148 | 4296 | 4444 | 5037 | 5185 | 5333 |
| 21 | 4200 | 4356 | 4511 | 4667 | 4822 | 5444 | 5600 | 5756 |
| 22 | 4563 | 4730 | 4889 | 5052 | 5215 | 5867 | 6030 | 6193 |
| 23 | 4941 | 5111 | 5281 | 5452 | 5622 | 6304 | 6474 | 6644 |
| 24 | 5333 | 5511 | 5689 | 5867 | 6044 | 6756 | 6933 | 7111 |
| 25 | 5741 | 5926 | 6111 | 6296 | 6481 | 7222 | 7407 | 7593 |
| 26 | 6163 | 6356 | 6548 | 6741 | 6933 | 7704 | 7896 | 8089 |
| 27 | 6600 | 6800 | 7000 | 7200 | 7400 | 8200 | 8400 | 8600 |
| 28 | 7052 | 7259 | 7467 | 7674 | 7881 | 8711 | 8919 | 9126 |
| 29 | 7519 | 7733 | 7948 | 8163 | 8378 | 9237 | 9452 | 9667 |
| 30 | 8000 | 8222 | 8444 | 8667 | 8889 | 9778 | 10000 | 10222 |
| 31 | 8496 | 8726 | 8956 | 9185 | 9415 | 10333 | 10563 | 10793 |
| 32 | 9007 | 9244 | 9481 | 9719 | 9956 | 10904 | 11141 | 11378 |
| 33 | 9533 | 9778 | 10022 | 10267 | 10511 | 11489 | 11733 | 11978 |
| 34 | 10074 | 10326 | 10578 | 10830 | 11081 | 12089 | 12341 | 12593 |
| 35 | 10630 | 10889 | 11148 | 11407 | 11667 | 12704 | 12963 | 13222 |
| 36 | 11200 | 11467 | 11733 | 12000 | 12267 | 13333 | 13600 | 13867 |
| 37 | 11785 | 12059 | 12333 | 12607 | 12881 | 13978 | 14252 | 14526 |
| 38 | 12385 | 12667 | 12948 | 13230 | 13511 | 14637 | 14919 | 15200 |
| 39 | 13000 | 13289 | 13578 | 13867 | 14156 | 15311 | 15600 | 15889 |
| 40 | 13630 | 13926 | 14222 | 14519 | 14815 | 16000 | 16296 | 16593 |
| 41 | 14274 | 14578 | 14881 | 15185 | 15489 | 16704 | 17007 | 17311 |
| 42 | 14933 | 15244 | 15556 | 15867 | 16178 | 17422 | 17733 | 18044 |
| 43 | 15607 | 15926 | 16224 | 16563 | 16881 | 18156 | 18474 | 18793 |
| 44 | 16296 | 16622 | 16948 | 17274 | 17600 | 18904 | 19230 | 19556 |
| 45 | 17000 | 17333 | 17667 | 18000 | 18333 | 19667 | 20000 | 20333 |
| 46 | 17719 | 18059 | 18400 | 18741 | 19081 | 20444 | 20785 | 21126 |
| 47 | 18452 | 18800 | 19148 | 19496 | 19844 | 21237 | 21585 | 21933 |
| 48 | 19200 | 19556 | 19911 | 20267 | 20622 | 22044 | 22400 | 22756 |
| 49 | 19963 | 20326 | 20689 | 21052 | 21415 | 22867 | 23230 | 23593 |
| 50 | 20741 | 20711 | 21481 | 21852 | 22222 | 23704 | 24074 | 24444 |
| 51 | 21533 | 21911 | 22289 | 22667 | 23044 | 24556 | 24933 | 25311 |
| 52 | 22341 | 22726 | 23111 | 23496 | 23881 | 25422 | 25807 | 26193 |
| 53 | 23163 | 23556 | 23948 | 24341 | 24733 | 26304 | 26696 | 27089 |
| 54 | 24000 | 24400 | 24800 | 25200 | 25600 | 27200 | 27600 | 28000 |
| 55 | 24852 | 25259 | 25667 | 26074 | 26481 | 28111 | 28519 | 28926 |
| 56 | 25719 | 26133 | 26548 | 26963 | 27378 | 29037 | 29452 | 29867 |
| 57 | 26600 | 27022 | 27444 | 27867 | 28289 | 29978 | 30400 | 30822 |
| 58 | 27496 | 27926 | 28356 | 28785 | 29215 | 30933 | 31363 | 31793 |
| 59 | 28407 | 28844 | 29281 | 29719 | 30156 | 31904 | 32341 | 32778 |
| 60 | 29333 | 29778 | 30222 | 30667 | 31111 | 32889 | 33333 | 33778 |

## XIX.—CUBIC YARDS PER 100 FEET. SLOPES 3 : 1.

| Depth | Base 12 | Base 14 | Base 16 | Base 18 | Base 20 | Base 28 | Base 30 | Base 32 |
|---|---|---|---|---|---|---|---|---|
| 1 | 56 | 63 | 70 | 78 | 85 | 115 | 122 | 130 |
| 2 | 133 | 148 | 163 | 178 | 193 | 252 | 267 | 281 |
| 3 | 233 | 256 | 278 | 300 | 322 | 411 | 433 | 456 |
| 4 | 356 | 385 | 415 | 444 | 474 | 593 | 622 | 652 |
| 5 | 500 | 537 | 574 | 611 | 648 | 796 | 833 | 870 |
| 6 | 667 | 711 | 756 | 800 | 844 | 1022 | 1067 | 1111 |
| 7 | 856 | 907 | 959 | 1011 | 1063 | 1270 | 1322 | 1374 |
| 8 | 1067 | 1126 | 1185 | 1244 | 1304 | 1541 | 1600 | 1659 |
| 9 | 1300 | 1367 | 1433 | 1500 | 1567 | 1833 | 1900 | 1967 |
| 10 | 1556 | 1630 | 1704 | 1778 | 1852 | 2148 | 2222 | 2296 |
| 11 | 1833 | 1915 | 1996 | 2078 | 2159 | 2485 | 2567 | 2648 |
| 12 | 2133 | 2222 | 2311 | 2400 | 2489 | 2844 | 2933 | 3022 |
| 13 | 2456 | 2552 | 2648 | 2744 | 2841 | 3226 | 3322 | 3419 |
| 14 | 2800 | 2904 | 3007 | 3111 | 3215 | 3630 | 3733 | 3837 |
| 15 | 3167 | 3278 | 3389 | 3500 | 3611 | 4056 | 4167 | 4278 |
| 16 | 3556 | 3674 | 3793 | 3911 | 4030 | 4504 | 4622 | 4741 |
| 17 | 3967 | 4093 | 4219 | 4344 | 4470 | 4974 | 5100 | 5226 |
| 18 | 4400 | 4533 | 4667 | 4800 | 4933 | 5467 | 5600 | 5733 |
| 19 | 4856 | 4996 | 5137 | 5278 | 5419 | 5981 | 6122 | 6263 |
| 20 | 5333 | 5481 | 5630 | 5778 | 5926 | 6519 | 6667 | 6815 |
| 21 | 5833 | 5989 | 6144 | 6300 | 6456 | 7078 | 7233 | 7389 |
| 22 | 6356 | 6519 | 6681 | 6844 | 7007 | 7659 | 7822 | 7985 |
| 23 | 6900 | 7070 | 7241 | 7411 | 7581 | 8263 | 8433 | 8504 |
| 24 | 7467 | 7644 | 7822 | 8000 | 8178 | 8889 | 9067 | 9144 |
| 25 | 8056 | 8241 | 8426 | 8611 | 8796 | 9537 | 9722 | 9807 |
| 26 | 8667 | 8859 | 9052 | 9244 | 9437 | 10207 | 10400 | 10593 |
| 27 | 9300 | 9500 | 9700 | 9900 | 10100 | 10900 | 11100 | 11300 |
| 28 | 9956 | 10163 | 10370 | 10578 | 10785 | 11615 | 11822 | 12030 |
| 29 | 10633 | 10848 | 11063 | 11278 | 11493 | 12352 | 12567 | 12781 |
| 30 | 11333 | 11556 | 11778 | 12000 | 12222 | 13111 | 13333 | 13556 |
| 31 | 12056 | 12285 | 12515 | 12744 | 12974 | 13893 | 14122 | 14352 |
| 32 | 12800 | 13037 | 13274 | 13511 | 13748 | 14696 | 14933 | 15170 |
| 33 | 13567 | 13811 | 14056 | 14300 | 14544 | 15522 | 15767 | 16011 |
| 34 | 14356 | 14607 | 14859 | 15111 | 15363 | 16370 | 16622 | 16874 |
| 35 | 15167 | 15426 | 15685 | 15944 | 16204 | 17241 | 17500 | 17759 |
| 36 | 16000 | 16267 | 16533 | 16800 | 17067 | 18133 | 18400 | 18667 |
| 37 | 16856 | 17130 | 17404 | 17678 | 17952 | 19048 | 19322 | 19596 |
| 38 | 17733 | 18015 | 18296 | 18578 | 18859 | 19985 | 20267 | 20548 |
| 39 | 18633 | 18922 | 19211 | 19500 | 19789 | 20944 | 21233 | 21522 |
| 40 | 19556 | 19852 | 20148 | 20444 | 20741 | 21926 | 22222 | 22516 |
| 41 | 20500 | 20804 | 21107 | 21411 | 21715 | 22930 | 23233 | 23537 |
| 42 | 21467 | 21778 | 22089 | 22400 | 22711 | 23956 | 24267 | 24578 |
| 43 | 22456 | 22774 | 23093 | 23411 | 23730 | 25004 | 25322 | 25641 |
| 44 | 23467 | 23793 | 24119 | 24444 | 24770 | 26074 | 26400 | 26726 |
| 45 | 24500 | 24833 | 25167 | 25500 | 25833 | 27167 | 27500 | 27833 |
| 46 | 25556 | 25896 | 26237 | 26578 | 26919 | 28281 | 28622 | 28963 |
| 47 | 26633 | 26981 | 27330 | 27678 | 28026 | 29419 | 29767 | 30115 |
| 48 | 27733 | 28089 | 28444 | 28800 | 29156 | 30578 | 30933 | 31289 |
| 49 | 28856 | 29219 | 29581 | 29944 | 30307 | 31759 | 32122 | 32485 |
| 50 | 30000 | 30370 | 30741 | 31111 | 31481 | 32963 | 33333 | 33704 |
| 51 | 31167 | 31544 | 31922 | 32300 | 32678 | 34189 | 34567 | 34944 |
| 52 | 32356 | 32741 | 33126 | 33511 | 33896 | 35437 | 35822 | 36207 |
| 53 | 33567 | 33959 | 34352 | 34744 | 35137 | 36707 | 37100 | 37493 |
| 54 | 34800 | 35200 | 35600 | 36000 | 36400 | 38000 | 38400 | 38800 |
| 55 | 36056 | 36463 | 36870 | 37278 | 37685 | 39315 | 39722 | 40130 |
| 56 | 37333 | 37748 | 38163 | 38578 | 38993 | 40652 | 41067 | 41481 |
| 57 | 38633 | 39056 | 39478 | 39900 | 40322 | 42011 | 42433 | 42856 |
| 58 | 39956 | 40385 | 40815 | 41244 | 41674 | 43393 | 43822 | 44252 |
| 59 | 41300 | 41737 | 42174 | 42611 | 43048 | 44796 | 45233 | 45670 |
| 60 | 42667 | 43111 | 43556 | 44000 | 44444 | 46222 | 46667 | 47111 |

## TABLE XX.—CUBIC YARDS IN 100 FEET LENGTH.

| Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.7 | 51 | 188.9 | 101 | 374.1 | 151 | 559.3 | 201 | 744.4 |
| 2 | 7.4 | 52 | 192.6 | 102 | 377.8 | 152 | 563.0 | 202 | 748.2 |
| 3 | 11.1 | 53 | 196.3 | 103 | 381.5 | 153 | 566.7 | 203 | 751.9 |
| 4 | 14.8 | 54 | 200.0 | 104 | 385.2 | 154 | 570.4 | 204 | 755.6 |
| 5 | 18.5 | 55 | 203.7 | 105 | 388.9 | 155 | 574.1 | 205 | 759.3 |
| 6 | 22.2 | 56 | 207.4 | 106 | 392.6 | 156 | 577.8 | 206 | 763.0 |
| 7 | 25.9 | 57 | 211.1 | 107 | 396.3 | 157 | 581.5 | 207 | 766.7 |
| 8 | 29.6 | 58 | 214.8 | 108 | 400.0 | 158 | 585.2 | 208 | 770.4 |
| 9 | 33.3 | 59 | 218.5 | 109 | 403.7 | 159 | 588.9 | 209 | 774.1 |
| 10 | 37.0 | 60 | 222.2 | 110 | 407.4 | 160 | 592.6 | 210 | 777.8 |
| 11 | 40.7 | 61 | 225.9 | 111 | 411.1 | 161 | 596.3 | 211 | 781.5 |
| 12 | 44.4 | 62 | 229.6 | 112 | 414.8 | 162 | 600.0 | 212 | 785.2 |
| 13 | 48.1 | 63 | 233.3 | 113 | 418.5 | 163 | 603.7 | 213 | 788.9 |
| 14 | 51.9 | 64 | 237.0 | 114 | 422.2 | 164 | 607.4 | 214 | 792.6 |
| 15 | 55.6 | 65 | 240.7 | 115 | 425.9 | 165 | 611.1 | 215 | 796.3 |
| 16 | 59.3 | 66 | 244.4 | 116 | 429.6 | 166 | 614.8 | 216 | 800.0 |
| 17 | 63.0 | 67 | 248.2 | 117 | 433.3 | 167 | 618.5 | 217 | 803.7 |
| 18 | 66.7 | 68 | 251.9 | 118 | 437.0 | 168 | 622.2 | 218 | 807.4 |
| 19 | 70.4 | 69 | 255.6 | 119 | 440.7 | 169 | 625.9 | 219 | 811.1 |
| 20 | 74.1 | 70 | 259.3 | 120 | 444.4 | 170 | 629.6 | 220 | 814.8 |
| 21 | 77.8 | 71 | 263.0 | 121 | 448.2 | 171 | 633.3 | 221 | 818.5 |
| 22 | 81.5 | 72 | 266.7 | 122 | 451.9 | 172 | 637.0 | 222 | 822.2 |
| 23 | 85.2 | 73 | 270.4 | 123 | 455.6 | 173 | 640.7 | 223 | 825.9 |
| 24 | 88.9 | 74 | 274.1 | 124 | 459.3 | 174 | 644.4 | 224 | 829.6 |
| 25 | 92.6 | 75 | 277.8 | 125 | 463.0 | 175 | 648.2 | 225 | 833.3 |
| 26 | 96.3 | 76 | 281.5 | 126 | 466.7 | 176 | 651.9 | 226 | 837.0 |
| 27 | 100.0 | 77 | 285.2 | 127 | 470.4 | 177 | 655.6 | 227 | 840.7 |
| 28 | 103.7 | 78 | 288.9 | 128 | 474.1 | 178 | 659.3 | 228 | 844.4 |
| 29 | 107.4 | 79 | 292.6 | 129 | 477.8 | 179 | 663.0 | 229 | 848.2 |
| 30 | 111.1 | 80 | 296.3 | 130 | 481.5 | 180 | 666.7 | 230 | 851.9 |
| 31 | 114.8 | 81 | 300.0 | 131 | 485.2 | 181 | 670.4 | 231 | 855.6 |
| 32 | 118.5 | 82 | 303.7 | 132 | 488.9 | 182 | 674.1 | 232 | 859.3 |
| 33 | 122.2 | 83 | 307.4 | 133 | 492.6 | 183 | 677.8 | 233 | 863.0 |
| 34 | 125.9 | 84 | 311.1 | 134 | 496.3 | 184 | 681.5 | 234 | 866.7 |
| 35 | 129.6 | 85 | 314.8 | 135 | 500.0 | 185 | 685.2 | 235 | 870.4 |
| 36 | 133.3 | 86 | 318.5 | 136 | 503.7 | 186 | 688.9 | 236 | 874.1 |
| 37 | 137.0 | 87 | 322.2 | 137 | 507.4 | 187 | 692.6 | 237 | 877.8 |
| 38 | 140.7 | 88 | 325.9 | 138 | 511.1 | 188 | 696.3 | 238 | 881.5 |
| 39 | 144.4 | 89 | 329.6 | 139 | 514.8 | 189 | 700.0 | 239 | 885.2 |
| 40 | 148.2 | 90 | 333.3 | 140 | 518.5 | 190 | 703.7 | 240 | 888.9 |
| 41 | 151.9 | 91 | 337.0 | 141 | 522.2 | 191 | 707.4 | 241 | 892.6 |
| 42 | 155.6 | 92 | 340.7 | 142 | 525.9 | 192 | 711.1 | 242 | 896.3 |
| 43 | 159.3 | 93 | 344.4 | 143 | 529.6 | 193 | 714.8 | 243 | 900.0 |
| 44 | 163.0 | 94 | 348.2 | 144 | 533.3 | 194 | 718.5 | 244 | 903.7 |
| 45 | 166.7 | 95 | 351.9 | 145 | 537.0 | 195 | 722.2 | 245 | 907.4 |
| 46 | 170.4 | 96 | 355.6 | 146 | 540.7 | 196 | 725.9 | 246 | 911.1 |
| 47 | 174.1 | 97 | 359.3 | 147 | 544.4 | 197 | 729.6 | 247 | 914.8 |
| 48 | 177.8 | 98 | 363.0 | 148 | 548.2 | 198 | 733.3 | 248 | 918.5 |
| 49 | 181.5 | 99 | 366.7 | 149 | 551.9 | 199 | 737.0 | 249 | 922.2 |
| 50 | 185.2 | 100 | 370.4 | 150 | 555.6 | 200 | 740.7 | 250 | 925.9 |

## TABLE XX.—CUBIC YARDS IN 100 FEET LENGTH.

| Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. |
|---|---|---|---|---|---|---|---|---|---|
| 251 | 929.6 | 301 | 1114.8 | 351 | 1300.0 | 401 | 1485.2 | 451 | 1670.4 |
| 252 | 933.3 | 302 | 1118.5 | 352 | 1303.7 | 402 | 1488.9 | 452 | 1674.1 |
| 253 | 937.0 | 303 | 1122.2 | 353 | 1307.4 | 403 | 1492.6 | 453 | 1677.8 |
| 254 | 940.7 | 304 | 1125.9 | 354 | 1311.1 | 404 | 1496.3 | 454 | 1681.5 |
| 255 | 944.4 | 305 | 1129.6 | 355 | 1314.8 | 405 | 1500.0 | 455 | 1685.2 |
| 256 | 948.2 | 306 | 1133.3 | 356 | 1318.5 | 406 | 1503.7 | 456 | 1688.9 |
| 257 | 951.9 | 307 | 1137.0 | 357 | 1322.2 | 407 | 1507.4 | 457 | 1692.6 |
| 258 | 955.6 | 308 | 1140.7 | 358 | 1325.9 | 408 | 1511.1 | 458 | 1696.3 |
| 259 | 959.3 | 309 | 1144.4 | 359 | 1329.6 | 409 | 1514.8 | 459 | 1700.0 |
| 260 | 963.0 | 310 | 1148.2 | 360 | 1333.3 | 410 | 1518.5 | 460 | 1703.7 |
| 261 | 966.7 | 311 | 1151.9 | 361 | 1337.0 | 411 | 1522.2 | 461 | 1707.4 |
| 262 | 970.4 | 312 | 1155.6 | 362 | 1340.7 | 412 | 1525.9 | 462 | 1711.1 |
| 263 | 974.1 | 313 | 1159.3 | 363 | 1344.4 | 413 | 1529.6 | 463 | 1714.8 |
| 264 | 977.8 | 314 | 1163.0 | 364 | 1348.2 | 414 | 1533.3 | 464 | 1718.5 |
| 265 | 981.5 | 315 | 1166.7 | 365 | 1351.9 | 415 | 1537.0 | 465 | 1722.2 |
| 266 | 985.2 | 316 | 1170.4 | 366 | 1355.6 | 416 | 1540.7 | 466 | 1725.9 |
| 267 | 988.9 | 317 | 1174.1 | 367 | 1359.3 | 417 | 1544.4 | 467 | 1729.6 |
| 268 | 992.6 | 318 | 1177.8 | 368 | 1363.0 | 418 | 1548.2 | 468 | 1733.3 |
| 269 | 996.3 | 319 | 1181.5 | 369 | 1366.7 | 419 | 1551.9 | 469 | 1737.0 |
| 270 | 1000.0 | 320 | 1185.2 | 370 | 1370.4 | 420 | 1555.6 | 470 | 1740.7 |
| 271 | 1003.7 | 321 | 1188.9 | 371 | 1374.1 | 421 | 1559.3 | 471 | 1744.4 |
| 272 | 1007.4 | 322 | 1192.6 | 372 | 1377.8 | 422 | 1563.0 | 472 | 1748.2 |
| 273 | 1011.1 | 323 | 1196.3 | 373 | 1381.5 | 423 | 1566.7 | 473 | 1751.9 |
| 274 | 1014.8 | 324 | 1200.0 | 374 | 1385.2 | 424 | 1570.4 | 474 | 1755.6 |
| 275 | 1018.5 | 325 | 1203.7 | 375 | 1388.9 | 425 | 1574.1 | 475 | 1759.3 |
| 276 | 1022.2 | 326 | 1207.4 | 376 | 1392.6 | 426 | 1577.8 | 476 | 1763.0 |
| 277 | 1025.9 | 327 | 1211.1 | 377 | 1396.3 | 427 | 1581.5 | 477 | 1766.7 |
| 278 | 1029.6 | 328 | 1214.8 | 378 | 1400.0 | 428 | 1585.2 | 478 | 1770.4 |
| 279 | 1033.3 | 329 | 1218.5 | 379 | 1403.7 | 429 | 1588.9 | 479 | 1774.1 |
| 280 | 1037.0 | 330 | 1222.2 | 380 | 1407.4 | 430 | 1592.6 | 480 | 1777.8 |
| 281 | 1040.7 | 331 | 1225.9 | 381 | 1411.1 | 431 | 1596.3 | 481 | 1781.5 |
| 282 | 1044.4 | 332 | 1229.6 | 382 | 1414.8 | 432 | 1600.0 | 482 | 1785.2 |
| 283 | 1048.2 | 333 | 1233.3 | 383 | 1418.5 | 433 | 1603.7 | 483 | 1788.9 |
| 284 | 1051.9 | 334 | 1237.0 | 384 | 1422.2 | 434 | 1607.4 | 484 | 1792.6 |
| 285 | 1055.6 | 335 | 1240.7 | 385 | 1425.9 | 435 | 1611.1 | 485 | 1796.3 |
| 286 | 1059.3 | 336 | 1244.4 | 386 | 1429.6 | 436 | 1614.8 | 486 | 1800.0 |
| 287 | 1063.0 | 337 | 1248.2 | 387 | 1433.3 | 437 | 1618.5 | 487 | 1803.7 |
| 288 | 1066.7 | 338 | 1251.9 | 388 | 1437.0 | 438 | 1622.2 | 488 | 1807.4 |
| 289 | 1070.4 | 339 | 1255.6 | 389 | 1440.7 | 439 | 1625.9 | 489 | 1811.1 |
| 290 | 1074.1 | 340 | 1259.3 | 390 | 1444.4 | 440 | 1629.6 | 490 | 1814.8 |
| 291 | 1077.8 | 341 | 1263.0 | 391 | 1448.2 | 441 | 1633.3 | 491 | 1818.5 |
| 292 | 1081.5 | 342 | 1266.7 | 392 | 1451.9 | 442 | 1637.0 | 492 | 1822.2 |
| 293 | 1085.2 | 343 | 1270.4 | 393 | 1455.6 | 443 | 1640.7 | 493 | 1825.9 |
| 294 | 1088.9 | 344 | 1274.1 | 394 | 1459.3 | 444 | 1644.4 | 494 | 1829.6 |
| 295 | 1092.6 | 345 | 1277.8 | 395 | 1463.0 | 445 | 1648.2 | 495 | 1833.3 |
| 296 | 1096.3 | 346 | 1281.5 | 396 | 1466.7 | 446 | 1651.9 | 496 | 1837.0 |
| 297 | 1100.0 | 347 | 1285.2 | 397 | 1470.4 | 447 | 1655.6 | 497 | 1840.7 |
| 298 | 1103.7 | 348 | 1288.9 | 398 | 1474.1 | 448 | 1659.3 | 498 | 1844.4 |
| 299 | 1107.4 | 349 | 1292.6 | 399 | 1477.8 | 449 | 1663.0 | 499 | 1848.2 |
| 300 | 1111.1 | 350 | 1296.3 | 400 | 1481.5 | 450 | 1666.7 | 500 | 1851.9 |

| Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. |
|---|---|---|---|---|---|---|---|---|---|
| 501 | 1855.6 | 551 | 2040.7 | 601 | 2225.9 | 651 | 2411.1 | 701 | 2596.3 |
| 502 | 1859.3 | 552 | 2044.4 | 602 | 2229.6 | 652 | 2414.8 | 702 | 2600.0 |
| 503 | 1863.0 | 553 | 2048.2 | 603 | 2233.3 | 653 | 2418.5 | 703 | 2603.7 |
| 504 | 1866.7 | 554 | 2051.9 | 604 | 2237.0 | 654 | 2422.2 | 704 | 2607.4 |
| 505 | 1870.4 | 555 | 2055.6 | 605 | 2240.7 | 655 | 2425.9 | 705 | 2611.1 |
| 506 | 1874.1 | 556 | 2059.3 | 606 | 2244.4 | 656 | 2429.6 | 706 | 2614.8 |
| 507 | 1877.8 | 557 | 2063.0 | 607 | 2248.2 | 657 | 2433.3 | 707 | 2618.5 |
| 508 | 1881.5 | 558 | 2066.7 | 608 | 2251.9 | 658 | 2437.0 | 708 | 2622.2 |
| 509 | 1885.2 | 559 | 2070.4 | 609 | 2255.6 | 659 | 2440.7 | 709 | 2625.9 |
| 510 | 1888.9 | 560 | 2074.1 | 610 | 2259.3 | 660 | 2444.4 | 710 | 2629.6 |
| 511 | 1892.6 | 561 | 2077.8 | 611 | 2263.0 | 661 | 2448.2 | 711 | 2633.3 |
| 512 | 1896.3 | 562 | 2081.5 | 612 | 2266.7 | 662 | 2451.9 | 712 | 2637.0 |
| 513 | 1900.0 | 563 | 2085.2 | 613 | 2270.4 | 663 | 2455.6 | 713 | 2640.7 |
| 514 | 1903.7 | 564 | 2088.9 | 614 | 2274.1 | 664 | 2459.3 | 714 | 2644.4 |
| 515 | 1907.4 | 565 | 2092.6 | 615 | 2277.8 | 665 | 2463.0 | 715 | 2648.2 |
| 516 | 1911.1 | 566 | 2096.3 | 616 | 2281.5 | 666 | 2466.7 | 716 | 2651.9 |
| 517 | 1914.8 | 567 | 2100.0 | 617 | 2285.2 | 667 | 2470.4 | 717 | 2655.6 |
| 518 | 1918.5 | 568 | 2103.7 | 618 | 2288.9 | 668 | 2474.1 | 718 | 2659.3 |
| 519 | 1922.2 | 569 | 2107.4 | 619 | 2292.6 | 669 | 2477.8 | 719 | 2663.0 |
| 520 | 1925.9 | 570 | 2111.1 | 620 | 2296.3 | 670 | 2481.5 | 720 | 2666.7 |
| 521 | 1929.6 | 571 | 2114.8 | 621 | 2300.0 | 671 | 2485.2 | 721 | 2670.4 |
| 522 | 1933.3 | 572 | 2118.5 | 622 | 2303.7 | 672 | 2488.9 | 722 | 2674.1 |
| 523 | 1937.0 | 573 | 2122.2 | 623 | 2307.4 | 673 | 2492.6 | 723 | 2677.8 |
| 524 | 1940.7 | 574 | 2125.9 | 624 | 2311.1 | 674 | 2496.3 | 724 | 2681.5 |
| 525 | 1944.4 | 575 | 2129.6 | 625 | 2314.8 | 675 | 2500.0 | 725 | 2685.2 |
| 526 | 1948.2 | 576 | 2133.3 | 626 | 2318.5 | 676 | 2503.7 | 726 | 2688.9 |
| 527 | 1951.9 | 577 | 2137.0 | 627 | 2322.2 | 677 | 2507.4 | 727 | 2692.6 |
| 528 | 1955.6 | 578 | 2140.7 | 628 | 2325.9 | 678 | 2511.1 | 728 | 2696.3 |
| 529 | 1959.3 | 579 | 2144.4 | 629 | 2329.6 | 679 | 2514.8 | 729 | 2700.0 |
| 530 | 1963.0 | 580 | 2148.2 | 630 | 2333.3 | 680 | 2518.5 | 730 | 2703.7 |
| 531 | 1966.7 | 581 | 2151.9 | 631 | 2337.0 | 681 | 2522.2 | 731 | 2707.4 |
| 532 | 1970.4 | 582 | 2155.6 | 632 | 2340.7 | 682 | 2525.9 | 732 | 2711.1 |
| 533 | 1974.1 | 583 | 2159.3 | 633 | 2344.4 | 683 | 2529.6 | 733 | 2714.8 |
| 534 | 1977.8 | 584 | 2163.0 | 634 | 2348.2 | 684 | 2533.3 | 734 | 2718.5 |
| 535 | 1981.5 | 585 | 2166.7 | 635 | 2351.9 | 685 | 2537.0 | 735 | 2722.2 |
| 536 | 1985.2 | 586 | 2170.4 | 636 | 2355.6 | 686 | 2540.7 | 736 | 2725.9 |
| 537 | 1988.9 | 587 | 2174.1 | 637 | 2359.3 | 687 | 2544.4 | 737 | 2729.6 |
| 538 | 1992.6 | 588 | 2177.8 | 638 | 2363.0 | 688 | 2548.2 | 738 | 2733.3 |
| 539 | 1996.3 | 589 | 2181.5 | 639 | 2366.7 | 689 | 2551.9 | 739 | 2737.0 |
| 540 | 2000.0 | 590 | 2185.2 | 640 | 2370.4 | 690 | 2555.6 | 740 | 2740.7 |
| 541 | 2003.7 | 591 | 2188.9 | 641 | 2374.1 | 691 | 2559.3 | 741 | 2744.4 |
| 542 | 2007.4 | 592 | 2192.6 | 642 | 2377.8 | 692 | 2563.0 | 742 | 2748.2 |
| 543 | 2011.1 | 593 | 2196.3 | 643 | 2381.5 | 693 | 2566.7 | 743 | 2751.9 |
| 544 | 2014.8 | 594 | 2200.0 | 644 | 2385.2 | 694 | 2570.4 | 744 | 2755.6 |
| 545 | 2018.5 | 595 | 2203.7 | 645 | 2388.9 | 695 | 2574.1 | 745 | 2759.3 |
| 546 | 2022.2 | 596 | 2207.4 | 646 | 2392.6 | 696 | 2577.8 | 746 | 2763.0 |
| 547 | 2025.9 | 597 | 2211.1 | 647 | 2396.3 | 697 | 2581.5 | 747 | 2766.7 |
| 548 | 2029.6 | 598 | 2214.8 | 648 | 2400.0 | 698 | 2585.2 | 748 | 2770.4 |
| 549 | 2033.3 | 599 | 2218.5 | 649 | 2403.7 | 699 | 2588.9 | 749 | 2774.1 |
| 550 | 2037.0 | 600 | 2222.2 | 650 | 2407.4 | 700 | 2592.6 | 750 | 2777.8 |

| Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. | Cubic Yards. | Area. Sq. Ft. |
|---|---|---|---|---|---|---|---|---|
| 751 | 2781.5 | 801 | 2966.7 | 851 | 3151.9 | 901 | 3337.0 | 951 |
| 752 | 2785.2 | 802 | 2970.4 | 852 | 3155.6 | 902 | 3340.7 | 952 |
| 753 | 2788.9 | 803 | 2974.1 | 853 | 3159.3 | 903 | 3344.4 | 953 |
| 754 | 2792.6 | 804 | 2977.8 | 854 | 3163.0 | 904 | 3348.2 | 954 |
| 755 | 2796.3 | 805 | 2981.5 | 855 | 3166.7 | 905 | 3351.9 | 955 |
| 756 | 2800.0 | 806 | 2985.2 | 856 | 3170.4 | 906 | 3355.6 | 956 |
| 757 | 2803.7 | 807 | 2988.9 | 857 | 3174.1 | 907 | 3359.3 | 957 |
| 758 | 2807.4 | 808 | 2992.6 | 858 | 3177.8 | 908 | 3363.0 | 958 |
| 759 | 2811.1 | 809 | 2996.3 | 859 | 3181.5 | 909 | 3366.7 | 959 |
| 760 | 2814.8 | 810 | 3000.0 | 860 | 3185.2 | 910 | 3370.4 | 960 |
| 761 | 2818.5 | 811 | 3003.7 | 861 | 3188.9 | 911 | 3374.1 | 961 |
| 762 | 2822.2 | 812 | 3007.4 | 862 | 3192.6 | 912 | 3377.8 | 962 |
| 763 | 2825.9 | 813 | 3011.1 | 863 | 3196.3 | 913 | 3381.5 | 963 |
| 764 | 2829.6 | 814 | 3014.8 | 864 | 3200.0 | 914 | 3385.2 | 964 |
| 765 | 2833.3 | 815 | 3018.5 | 865 | 3203.7 | 915 | 3388.9 | 965 |
| 766 | 2837.0 | 816 | 3022.2 | 866 | 3207.4 | 916 | 3392.6 | 966 |
| 767 | 2840.7 | 817 | 3025.9 | 867 | 3211.1 | 917 | 3396.3 | 967 |
| 768 | 2844.4 | 818 | 3029.6 | 868 | 3214.8 | 918 | 3400.0 | 968 |
| 769 | 2848.2 | 819 | 3033.3 | 869 | 3218.5 | 919 | 3403.7 | 969 |
| 770 | 2851.9 | 820 | 3037.0 | 870 | 3222.2 | 920 | 3407.4 | 970 |
| 771 | 2855.6 | 821 | 3040.7 | 871 | 3225.9 | 921 | 3411.1 | 971 |
| 772 | 2859.3 | 822 | 3044.4 | 872 | 3229.6 | 922 | 3414.8 | 972 |
| 773 | 2863.0 | 823 | 3048.2 | 873 | 3233.3 | 923 | 3418.5 | 973 |
| 774 | 2866.7 | 824 | 3051.9 | 874 | 3237.0 | 924 | 3422.2 | 974 |
| 775 | 2870.4 | 825 | 3055.6 | 875 | 3240.7 | 925 | 3425.9 | 975 |
| 776 | 2874.1 | 826 | 3059.3 | 876 | 3244.4 | 926 | 3429.6 | 976 |
| 777 | 2877.8 | 827 | 3063.0 | 877 | 3248.2 | 927 | 3433.3 | 977 |
| 778 | 2881.5 | 828 | 3066.7 | 878 | 3251.9 | 928 | 3437.0 | 978 |
| 779 | 2885.2 | 829 | 3070.4 | 879 | 3255.6 | 929 | 3440.7 | 979 |
| 780 | 2888.9 | 830 | 3074.1 | 880 | 3259.3 | 930 | 3444.4 | 980 |
| 781 | 2892.6 | 831 | 3077.8 | 881 | 3263.0 | 931 | 3448.2 | 981 |
| 782 | 2896.3 | 832 | 3081.5 | 882 | 3266.7 | 932 | 3451.9 | 982 |
| 783 | 2900.0 | 833 | 3085.2 | 883 | 3270.4 | 933 | 3455.6 | 983 |
| 784 | 2903.7 | 834 | 3088.9 | 884 | 3274.1 | 934 | 3459.3 | 984 |
| 785 | 2907.4 | 835 | 3092.6 | 885 | 3277.8 | 935 | 3463.0 | 985 |
| 786 | 2911.1 | 836 | 3096.3 | 886 | 3281.5 | 936 | 3466.7 | 986 |
| 787 | 2914.8 | 837 | 3100.0 | 887 | 3285.2 | 937 | 3470.4 | 987 |
| 788 | 2918.5 | 838 | 3103.7 | 888 | 3288.9 | 938 | 3474.1 | 988 |
| 789 | 2922.2 | 839 | 3107.4 | 889 | 3292.6 | 939 | 3477.8 | 989 |
| 790 | 2925.9 | 840 | 3111.1 | 890 | 3296.3 | 940 | 3481.5 | 990 |
| 791 | 2929.6 | 841 | 3114.8 | 891 | 3300.0 | 941 | 3485.2 | 991 |
| 792 | 2933.3 | 842 | 3118.5 | 892 | 3303.7 | 942 | 3488.9 | 992 |
| 793 | 2937.0 | 843 | 3122.2 | 893 | 3307.4 | 943 | 3492.6 | 993 |
| 794 | 2940.7 | 844 | 3125.9 | 894 | 3311.1 | 944 | 3496.3 | 994 |
| 795 | 2944.4 | 845 | 3129.6 | 895 | 3314.8 | 945 | 3500.0 | 995 |
| 796 | 2948.2 | 846 | 3133.3 | 896 | 3318.5 | 946 | 3503.7 | 996 |
| 797 | 2951.9 | 847 | 3137.0 | 897 | 3322.2 | 947 | 3507.4 | 997 |
| 798 | 2955.6 | 848 | 3140.7 | 898 | 3325.9 | 948 | 3511.1 | 998 |
| 799 | 2959.3 | 849 | 3144.4 | 899 | 3329.6 | 949 | 3514.8 | 999 |
| 800 | 2963.0 | 850 | 3148.2 | 900 | 3333.3 | 950 | 3518.5 | 1000 |

| Rise per Cent. | Feet per Mile. | Rise per Cent. | Feet per Mile. | Rise per Cent. | Feet per Mile. | Rise per Cent. | Feet per Mile. |
|---|---|---|---|---|---|---|---|
| .01 | .528 | .61 | 32.208 | 1.21 | 63.888 | 1.81 | 95.568 |
| .02 | 1.056 | .62 | 32.736 | 1.22 | 64.416 | 1.82 | 96.096 |
| .03 | 1.584 | .63 | 33.264 | 1.23 | 64.944 | 1.83 | 96.624 |
| .04 | 2.112 | .64 | 33.792 | 1.24 | 65.472 | 1.84 | 97.152 |
| .05 | 2.640 | .65 | 34.320 | 1.25 | 66.000 | 1.85 | 97.680 |
| .06 | 3.168 | .66 | 34.848 | 1.26 | 66.528 | 1.86 | 98.208 |
| .07 | 3.696 | .67 | 35.376 | 1.27 | 67.056 | 1.87 | 98.736 |
| .08 | 4.224 | .68 | 35.904 | 1.28 | 67.584 | 1.88 | 99.264 |
| .09 | 4.752 | .69 | 36.432 | 1.29 | 68.112 | 1.89 | 99.792 |
| .10 | 5.280 | .70 | 36.960 | 1.30 | 68.640 | 1.90 | 100.320 |
| .11 | 5.808 | .71 | 37.488 | 1.31 | 69.168 | 1.91 | 100.848 |
| .12 | 6.336 | .72 | 38.016 | 1.32 | 69.696 | 1.92 | 101.376 |
| .13 | 6.864 | .73 | 38.544 | 1.33 | 70.224 | 1.93 | 101.904 |
| .14 | 7.392 | .74 | 39.072 | 1.34 | 70.752 | 1.94 | 102.432 |
| .15 | 7.920 | .75 | 39.600 | 1.35 | 71.280 | 1.95 | 102.960 |
| .16 | 8.448 | .76 | 40.128 | 1.36 | 71.808 | 1.96 | 103.488 |
| .17 | 8.976 | .77 | 40.656 | 1.37 | 72.336 | 1.97 | 104.016 |
| .18 | 9.504 | .78 | 41.184 | 1.38 | 72.864 | 1.98 | 104.544 |
| .19 | 10.032 | .79 | 41.712 | 1.39 | 73.392 | 1.99 | 105.072 |
| .20 | 10.560 | .80 | 42.240 | 1.40 | 73.920 | 2.00 | 105.600 |
| .21 | 11.088 | .81 | 42.768 | 1.41 | 74.448 | 2.10 | 110.880 |
| .22 | 11.616 | .82 | 43.296 | 1.42 | 74.976 | 2.20 | 116.160 |
| .23 | 12.144 | .83 | 43.824 | 1.43 | 75.504 | 2.30 | 121.440 |
| .24 | 12.672 | .84 | 44.352 | 1.44 | 76.032 | 2.40 | 126.720 |
| .25 | 13.200 | .85 | 44.880 | 1.45 | 76.560 | 2.50 | 132.000 |
| .26 | 13.728 | .86 | 45.408 | 1.46 | 77.088 | 2.60 | 137.280 |
| .27 | 14.256 | .87 | 45.936 | 1.47 | 77.616 | 2.70 | 142.560 |
| .28 | 14.784 | .88 | 46.464 | 1.48 | 78.144 | 2.80 | 147.840 |
| .29 | 15.312 | .89 | 46.992 | 1.49 | 78.672 | 2.90 | 153.120 |
| .30 | 15.840 | .90 | 47.520 | 1.50 | 79.200 | 3.00 | 158.400 |
| .31 | 16.368 | .91 | 48.048 | 1.51 | 79.728 | 3.10 | 163.680 |
| .32 | 16.896 | .92 | 48.576 | 1.52 | 80.256 | 3.20 | 168.960 |
| .33 | 17.424 | .93 | 49.104 | 1.53 | 80.784 | 3.30 | 174.240 |
| .34 | 17.952 | .94 | 49.632 | 1.54 | 81.312 | 3.40 | 179.520 |
| .35 | 18.480 | .95 | 50.160 | 1.55 | 81.840 | 3.50 | 184.800 |
| .36 | 19.008 | .96 | 50.688 | 1.56 | 82.368 | 3.60 | 190.080 |
| .37 | 19.536 | .97 | 51.216 | 1.57 | 82.896 | 3.70 | 195.360 |
| .38 | 20.064 | .98 | 51.744 | 1.58 | 83.424 | 3.80 | 200.640 |
| .39 | 20.592 | .99 | 52.272 | 1.59 | 83.952 | 3.90 | 205.920 |
| .40 | 21.120 | 1.00 | 52.800 | 1.60 | 84.480 | 4.00 | 211.200 |
| .41 | 21.648 | 1.01 | 53.328 | 1.61 | 85.008 | 4.10 | 216.480 |
| .42 | 22.176 | 1.02 | 53.856 | 1.62 | 85.536 | 4.20 | 221.760 |
| .43 | 22.704 | 1.03 | 54.384 | 1.63 | 86.064 | 4.30 | 227.040 |
| .44 | 23.232 | 1.04 | 54.912 | 1.64 | 86.592 | 4.40 | 232.320 |
| .45 | 23.760 | 1.05 | 55.440 | 1.65 | 87.120 | 4.50 | 237.600 |
| .46 | 24.288 | 1.06 | 55.968 | 1.66 | 87.648 | 4.60 | 242.880 |
| .47 | 24.816 | 1.07 | 56.496 | 1.67 | 88.176 | 4.70 | 248.160 |
| .48 | 25.344 | 1.08 | 57.024 | 1.68 | 88.704 | 4.80 | 253.440 |
| .49 | 25.872 | 1.09 | 57.552 | 1.69 | 89.232 | 4.90 | 258.720 |
| .50 | 26.400 | 1.10 | 58.080 | 1.70 | 89.760 | 5.00 | 264.000 |
| .51 | 26.928 | 1.11 | 58.608 | 1.71 | 90.288 | 5.10 | 269.280 |
| .52 | 27.456 | 1.12 | 59.136 | 1.72 | 90.816 | 5.20 | 274.560 |
| .53 | 27.984 | 1.13 | 59.664 | 1.73 | 91.344 | 5.30 | 279.840 |
| .54 | 28.512 | 1.14 | 60.192 | 1.74 | 91.872 | 5.40 | 285.120 |
| .55 | 29.040 | 1.15 | 60.720 | 1.75 | 92.400 | 5.50 | 290.400 |
| .56 | 29.568 | 1.16 | 61.248 | 1.76 | 92.928 | 5.60 | 295.680 |
| .57 | 30.096 | 1.17 | 61.776 | 1.77 | 93.456 | 5.70 | 300.960 |
| .58 | 30.624 | 1.18 | 62.304 | 1.78 | 93.984 | 5.80 | 306.240 |
| .59 | 31.152 | 1.19 | 62.832 | 1.79 | 94.512 | 5.90 | 311.520 |
| .60 | 31.680 | 1.20 | 63.360 | 1.80 | 95.040 | 6.00 | 316.800 |

## TABLE XXII.—SLOPES FOR TOPOGRAPHY.

| Angle of Inclination. | Vertical Rise in 100 Horizontal. | Horizontal Distance to a Rise of 10. | Angle of Inclination. | Vertical Rise in 100 Horizontal. | Horizontal Distance to a Rise of 10. | Angle of Inclination. | Vertical Rise in 100 Horizontal. | Horizontal Distance to a Rise of 10. |
|---|---|---|---|---|---|---|---|---|
| 0° 20′ | .58 | 1718.9 | 7° 20′ | 12.87 | 77.7 | 16° | 28.67 | 34.9 |
| 40 | 1.16 | 859.4 | 40 | 13.46 | 74.3 | 17 | 30.57 | 32.7 |
| 1 | 1.75 | 572.9 | 8 | 14.05 | 71.2 | 18 | 32.49 | 30.8 |
| 20 | 2.33 | 429.6 | 20 | 14.65 | 68.3 | 19 | 34.43 | 29.0 |
| 40 | 2.91 | 343.7 | 40 | 15.24 | 65.6 | 20 | 36.40 | 27.5 |
| 2 | 3.49 | 286.4 | 9 | 15.84 | 63.1 | 21 | 38.39 | 26.1 |
| 20 | 4.08 | 245.4 | 20 | 16.44 | 60.8 | 22 | 40.40 | 24.8 |
| 40 | 4.66 | 214.7 | 40 | 17.03 | 58.7 | 23 | 42.45 | 23.6 |
| 3 | 5.24 | 190.8 | 10 | 17.63 | 56.7 | 24 | 44.52 | 22.5 |
| 20 | 5.82 | 171.7 | 20 | 18.23 | 54.8 | 25 | 46.63 | 21.4 |
| 40 | 6.41 | 156.0 | 40 | 18.84 | 53.1 | 26 | 48.77 | 20.5 |
| 4 | 6.99 | 143.0 | 11 | 19.44 | 51.4 | 27 | 50.95 | 19.6 |
| 20 | 7.58 | 132.0 | 30 | 20.35 | 49.2 | 28 | 53.17 | 18.8 |
| 40 | 8.16 | 122.5 | 12 | 21.26 | 47.0 | 29 | 55.43 | 18.0 |
| 5 | 8.75 | 114.3 | 30 | 22.17 | 45.1 | 30 | 57.74 | 17.3 |
| 20 | 9.34 | 107.1 | 13 | 23.09 | 43.3 | 35 | 70.02 | 14.3 |
| 40 | 9.92 | 100.8 | 30 | 24.01 | 41.7 | 40 | 83.91 | 11.9 |
| 6 | 10.51 | 95.1 | 14 | 24.93 | 40.1 | 45 | 100.00 | 10.0 |
| 20 | 11.10 | 90.1 | 30 | 25.86 | 38.7 | 50 | 119.18 | 8.4 |
| 40 | 11.69 | 85.6 | 15 | 26.79 | 37.3 | 55 | 142.81 | 7.0 |
| 7 | 12.28 | 81.4 | 30 | 27.73 | 36.1 | 60 | 173.21 | 5.8 |

## TABLE XXIII.—MATERIAL REQUIRED FOR ONE MILE OF TRACK.

| RAIL WEIGHTS. | | | RAILROAD SPIKES. | | | | |
|---|---|---|---|---|---|---|---|
| Pounds per Yard. | Short Tons of 2000 lbs. | Long Tons of 2240 lbs. | Size under Head. | Average No. per Keg of 200 lbs. | Required for Ties 2 ft. Apart. Weight in Lbs. | Required for Ties 2 ft. Apart. No. of Kegs. | For Rails Weighing |
| 12 | 21.12 | 18.857 | $5\frac{1}{2}\times\frac{9}{16}$ | 360 | 5870 | 29.3 | 45 to 70 lbs. |
| 16 | 28.16 | 25.143 | $5\times\frac{9}{16}$ | 400 | 5280 | 26.4 | 40 " 56 " |
| 20 | 35.20 | 31.429 | $5\times\frac{1}{2}$ | 450 | 4690 | 23.5 | 35 " 40 " |
| 25 | 44.00 | 39.286 | $4\frac{1}{2}\times\frac{1}{2}$ | 530 | 3980 | 19.9 | 28 " 35 " |
| 30 | 52.80 | 47.143 | $4\times\frac{1}{2}$ | 600 | 3520 | 17.6 | 24 " 35 " |
| 35 | 61.60 | 55.000 | $4\frac{1}{2}\times\frac{7}{16}$ | 680 | 3110 | 15.5 | 20 " 30 " |
| 40 | 70.40 | 62.857 | $4\times\frac{7}{16}$ | 720 | 2930 | 14.7 | 20 " 30 " |
| 45 | 79.20 | 70.714 | $3\frac{1}{2}\times\frac{7}{16}$ | 900 | 2350 | 11.7 | 16 " 25 " |
| 56 | 98.56 | 88.000 | $4\times\frac{3}{8}$ | 1000 | 2110 | 10.6 | 16 " 25 " |
| 60 | 105.60 | 94.286 | $3\frac{1}{4}\times\frac{3}{8}$ | 1190 | 1770 | 8.9 | 16 " 20 " |
| 70 | 123.20 | 110.000 | $3\times\frac{3}{8}$ | 1240 | 1700 | 8.5 | 16 " 20 " |
| 80 | 140.80 | 125.714 | $2\frac{1}{2}\times\frac{3}{8}$ | 1342 | 1570 | 7.9 | 12 " 16 " |

| NUMBER OF CROSS-TIES. | | | | |
|---|---|---|---|---|
| Distance apart, c. to c., in Feet. | | | | |
| 1.5 | 1.75 | 2.0 | 2.25 | 2.50 |
| 3520 | 3017 | 2640 | 2347 | 2112 |

| NUMBER OF SPLICE-JOINTS. Two Bars with Four Bolts and Nuts to Each Joint. | | | | |
|---|---|---|---|---|
| Length of Rail in Feet. | | | | |
| 20 | 24 | 26 | 28 | 30 |
| 528 | 440 | 406 | 377 | 352 |

## CONVERSION OF ENGLISH INCHES INTO CENTIMETRES.

| Ins. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cm. | Cm. | Cm. | Cm. | Cm. | Cm. | Cm. | Cm. | Cm. | Cm. |
| 0 | 0.000 | 2.540 | 5.080 | 7.620 | 10.16 | 12.70 | 15.24 | 17.78 | 20.32 | 22.86 |
| 10 | 25.40 | 27.94 | 30.48 | 33.02 | 35.56 | 38.10 | 40.64 | 43.18 | 45.72 | 48.26 |
| 20 | 50.80 | 53.34 | 55.88 | 58.42 | 60.96 | 63.50 | 66.04 | 68.58 | 71.12 | 73.66 |
| 30 | 76.20 | 78.74 | 81.28 | 83.82 | 86.36 | 88.90 | 91.44 | 93.98 | 96.52 | 99.06 |
| 40 | 101.60 | 104.14 | 106.68 | 109.22 | 111.76 | 114.30 | 116.84 | 119.38 | 121.92 | 124.46 |
| 50 | 127.00 | 129.54 | 132.08 | 134.62 | 137.16 | 139.70 | 142.24 | 144.78 | 147.32 | 149.86 |
| 60 | 152.40 | 154.94 | 157.48 | 160.02 | 162.56 | 165.10 | 167.64 | 170.18 | 172.72 | 175.26 |
| 70 | 177.80 | 180.34 | 182.88 | 185.42 | 187.96 | 190.50 | 193.04 | 195.58 | 198.12 | 200.66 |
| 80 | 203.20 | 205.74 | 208.28 | 210.82 | 213.36 | 215.90 | 218.44 | 220.98 | 223.52 | 226.06 |
| 90 | 228.60 | 231.14 | 233.68 | 236.22 | 238.76 | 241.30 | 243.84 | 246.38 | 248.92 | 251.46 |
| 100 | 254.00 | 256.54 | 259.08 | 261.62 | 264.16 | 266.70 | 269.24 | 271.78 | 274.32 | 276.86 |

## CONVERSION OF CENTIMETRES INTO ENGLISH INCHES.

| Cm. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. |
| 0 | 0.000 | 0.394 | 0.787 | 1.181 | 1.575 | 1.969 | 2.362 | 2.756 | 3.150 | 3.543 |
| 10 | 3.937 | 4.331 | 4.742 | 5.118 | 5.512 | 5.906 | 6.299 | 6.693 | 7.087 | 7.480 |
| 20 | 7.874 | 8.268 | 8.662 | 9.055 | 9.449 | 9.843 | 10.236 | 10.630 | 11.024 | 11.413 |
| 30 | 11.811 | 12.205 | 12.599 | 12.992 | 13.386 | 13.780 | 14.173 | 14.567 | 14.961 | 15.355 |
| 40 | 15.748 | 16.142 | 16.536 | 16.929 | 17.323 | 17.717 | 18.111 | 18.504 | 18.898 | 19.292 |
| 50 | 19.685 | 20.079 | 20.473 | 20.867 | 21.260 | 21.654 | 22.048 | 22.441 | 22.835 | 23.229 |
| 60 | 23.622 | 24.016 | 24.410 | 24.804 | 25.197 | 25.591 | 25.985 | 26.378 | 26.772 | 27.166 |
| 70 | 27.560 | 27.953 | 28.347 | 28.741 | 29.134 | 29.528 | 29.922 | 30.316 | 30.709 | 31.103 |
| 80 | 31.497 | 31.890 | 32.284 | 32.678 | 33.071 | 33.465 | 33.859 | 34.253 | 34.646 | 35.040 |
| 90 | 35.434 | 35.827 | 36.221 | 36.615 | 37.009 | 37.402 | 37.796 | 38.190 | 38.583 | 38.977 |
| 100 | 39.370 | 39.764 | 40.158 | 40.552 | 40.945 | 41.339 | 41.733 | 42.126 | 42.520 | 42.914 |

## CONVERSION OF ENGLISH FEET INTO METRES.

| Feet | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Met. | Met. | Met. | Met. | Met. | Met. | Met. | Met. | Met. | Met. |
| 0 | 0.000 | 0.3048 | 0.6096 | 0.9144 | 1.2192 | 1.5239 | 1.8287 | 2.1335 | 2.4383 | 2.7431 |
| 10 | 3.0479 | 3.3527 | 3.6575 | 3.9623 | 4.2671 | 4.5719 | 4.8767 | 5.1815 | 5.4863 | 5.7911 |
| 20 | 6.0959 | 6.4006 | 6.7055 | 7.0102 | 7.3150 | 7.6198 | 7.9246 | 8.2294 | 8.5342 | 8.8390 |
| 30 | 9.1438 | 9.4486 | 9.7534 | 10.058 | 10.363 | 10.668 | 10.972 | 11.277 | 11.582 | 11.887 |
| 40 | 12.192 | 12.496 | 12.801 | 13.106 | 13.411 | 13.716 | 14.020 | 14.325 | 14.630 | 14.935 |
| 50 | 15.239 | 15.544 | 15.849 | 16.154 | 16.459 | 16.763 | 17.068 | 17.373 | 17.678 | 17.983 |
| 60 | 18.287 | 18.592 | 18.897 | 19.202 | 19.507 | 19.811 | 20.116 | 20.421 | 20.726 | 21.031 |
| 70 | 21.335 | 21.640 | 21.945 | 22.250 | 22.555 | 22.859 | 23.164 | 23.469 | 23.774 | 24.079 |
| 80 | 24.383 | 24.688 | 24.993 | 25.298 | 25.602 | 25.907 | 26.212 | 26.517 | 26.822 | 27.126 |
| 90 | 27.431 | 27.736 | 28.041 | 28.346 | 28.651 | 28.955 | 29.260 | 29.565 | 29.870 | 30.174 |
| 100 | 30.479 | 30.784 | 31.089 | 31.394 | 31.698 | 32.003 | 32.308 | 32.613 | 32.918 | 33.222 |

## CONVERSION OF METRES INTO ENGLISH FEET.

| Met. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. |
| 0 | 0.000 | 3.2809 | 6.5618 | 9.8427 | 13.123 | 16.404 | 19.685 | 22.966 | 26.247 | 29.528 |
| 10 | 32.809 | 36.090 | 39.371 | 42.651 | 45.932 | 49.213 | 52.494 | 55.775 | 59.056 | 62.337 |
| 20 | 65.618 | 68.899 | 72.179 | 75.461 | 78.741 | 82.022 | 85.303 | 88.584 | 91.865 | 95.146 |
| 30 | 98.427 | 101.71 | 104.99 | 108.27 | 111 55 | 114.83 | 118.11 | 121.39 | 124.67 | 127.96 |
| 40 | 131.24 | 134.52 | 137.80 | 141.08 | 144.36 | 147.64 | 150 92 | 154.20 | 157.48 | 160.76 |
| 50 | 164.04 | 167.33 | 170 61 | 173.89 | 177.17 | 180.45 | 183.73 | 187.01 | 190.29 | 193.57 |
| 60 | 196.85 | 200.13 | 203.42 | 206.70 | 209.98 | 213.26 | 216.54 | 219.82 | 223.10 | 226.38 |
| 70 | 229.66 | 232.94 | 236.22 | 239.51 | 242.79 | 246.07 | 249.35 | 252 63 | 255.91 | 259.19 |
| 80 | 262.47 | 265.75 | 269.03 | 272.31 | 275.60 | 278.88 | 282.16 | 285.44 | 288.72 | 292.00 |
| 90 | 295.28 | 298.56 | 301.84 | 305.12 | 308.40 | 311.69 | 314.97 | 318.25 | 321.53 | 324.81 |
| 100 | 328.09 | 331.37 | 334.65 | 337.93 | 341.21 | 344.49 | 347.78 | 351.06 | 354.34 | 357.02 |

## TABLE XXV.

### CONVERSION OF ENGLISH STATUTE-MILES INTO KILOMETRES.

| Miles. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kilo. | Kilo. | Kilo. | Kilo. | Kilo. | Kilo. | Kilo. | Kilo. | Kilo. | Kilo. |
| 0 | 0.0000 | 1.6093 | 3.2186 | 4.8279 | 6.4372 | 8.0465 | 9.6558 | 11.2652 | 12.8745 | 14.4818 |
| 10 | 16.093 | 17.702 | 19.312 | 20.921 | 22.530 | 24.139 | 25.749 | 27.358 | 28.967 | 30.577 |
| 20 | 32.186 | 33.795 | 35.405 | 37.014 | 38.623 | 40.232 | 41.842 | 43.451 | 45.060 | 46.670 |
| 30 | 48.279 | 49.888 | 51.498 | 53.107 | 54.716 | 56.325 | 57.935 | 59.544 | 61.153 | 62.763 |
| 40 | 64.372 | 65.981 | 67.591 | 69.200 | 70.809 | 72.418 | 74.028 | 75.637 | 77.246 | 78.856 |
| 50 | 80.465 | 82.074 | 83.684 | 85.293 | 86.902 | 88.511 | 90.121 | 91.730 | 93.339 | 94.949 |
| 60 | 96.558 | 98.167 | 99.777 | 101.39 | 102.99 | 104.60 | 106.21 | 107.82 | 109.43 | 111.04 |
| 70 | 112.65 | 114.26 | 115.87 | 117.48 | 119.08 | 120.69 | 122.30 | 123.91 | 125.52 | 127.13 |
| 80 | 128.74 | 130.35 | 131.96 | 133.57 | 135.17 | 136.78 | 138.39 | 140.00 | 141.61 | 143.22 |
| 90 | 144.85 | 146.44 | 148.05 | 149.66 | 151.26 | 152.87 | 154.48 | 156.09 | 157.70 | 159.31 |
| 100 | 160.93 | 162.53 | 164.14 | 165.75 | 167.35 | 168.96 | 170.57 | 172.18 | 173.79 | 175.40 |

### CONVERSION OF KILOMETRES INTO ENGLISH STATUTE-MILES.

| Kilom. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Miles. | Miles. | Miles. | Miles. | Miles. | Miles. | Miles. | Miles. | Miles. | Miles. |
| 0 | 0.0000 | 0.6214 | 1.2427 | 1.8641 | 2.4855 | 3.1069 | 3.7282 | 4.3497 | 4.9711 | 5.5924 |
| 10 | 6.2138 | 6.8352 | 7.4565 | 8.0780 | 8.6994 | 9.3208 | 9.9421 | 10.562 | 11.185 | 11.805 |
| 20 | 12.427 | 13.049 | 13.670 | 14.292 | 14.913 | 15.534 | 16.156 | 16.776 | 17.399 | 18.019 |
| 30 | 18.641 | 19.263 | 19.884 | 20.506 | 21.127 | 21.748 | 23.370 | 22.990 | 23.613 | 24.233 |
| 40 | 24.855 | 25.477 | 26.098 | 26.720 | 27.341 | 27.962 | 28.584 | 29.204 | 29.827 | 30.447 |
| 50 | 31.069 | 31.690 | 32.311 | 32.933 | 33.554 | 34.175 | 34.797 | 35.417 | 36.040 | 36.660 |
| 60 | 37.282 | 37.904 | 38.525 | 39.147 | 39.768 | 40.389 | 41.011 | 41.631 | 42.254 | 42.874 |
| 70 | 43.497 | 44.118 | 44.739 | 45.361 | 45.982 | 46.603 | 47.225 | 47.845 | 48.468 | 49.088 |
| 80 | 49.711 | 50.332 | 50.953 | 51.575 | 52.196 | 52.817 | 53.439 | 54.059 | 54.682 | 55.302 |
| 90 | 55.924 | 56.545 | 57.166 | 57.788 | 58.409 | 59.030 | 59.652 | 60.272 | 60.895 | 61.515 |
| 100 | 62.138 | 62.759 | 63.380 | 64.002 | 64.623 | 65.244 | 65.866 | 66.486 | 67.109 | 67.729 |

## TABLE XXVI.

### LENGTH IN FEET OF 1′ ARCS OF LATITUDE AND LONGITUDE.

| Lat. | 1′ Lat. | 1′ Long. | Lat. | 1′ Lat. | 1′ Long. |
|---|---|---|---|---|---|
| 1° | 6045 | 6085 | 31° | 6061 | 5222 |
| 2° | 6045 | 6083 | 32° | 6062 | 5166 |
| 3° | 6045 | 6078 | 33° | 6063 | 5109 |
| 4° | 6045 | 6071 | 34° | 6064 | 5051 |
| 5° | 6045 | 6063 | 35° | 6065 | 4991 |
| 6° | 6045 | 6053 | 36° | 6066 | 4930 |
| 7° | 6046 | 6041 | 37° | 6067 | 4867 |
| 8° | 6046 | 6027 | 38° | 6068 | 4802 |
| 9° | 6046 | 6012 | 39° | 6070 | 4736 |
| 10° | 6047 | 5994 | 40° | 6071 | 4669 |
| 11° | 6047 | 5975 | 41° | 6072 | 4600 |
| 12° | 6048 | 5954 | 42° | 6073 | 4530 |
| 13° | 6048 | 5931 | 43° | 6074 | 4458 |
| 14° | 6049 | 5907 | 44° | 6075 | 4385 |
| 15° | 6049 | 5880 | 45° | 6076 | 4311 |
| 16° | 6050 | 5852 | 46° | 6077 | 4235 |
| 17° | 6050 | 5822 | 47° | 6078 | 4158 |
| 18° | 6051 | 5790 | 48° | 6079 | 4080 |
| 19° | 6052 | 5757 | 49° | 6080 | 4001 |
| 20° | 6052 | 5721 | 50° | 6081 | 3920 |
| 21° | 6053 | 5684 | 51° | 6082 | 3838 |
| 22° | 6054 | 5646 | 52° | 6084 | 3755 |
| 23° | 6054 | 5605 | 53° | 6085 | 3671 |
| 24° | 6055 | 5563 | 54° | 6086 | 3586 |
| 25° | 6056 | 5519 | 55° | 6087 | 3499 |
| 26° | 6057 | 5474 | 56° | 6088 | 3418 |
| 27° | 6058 | 5427 | 57° | 6089 | 3323 |
| 28° | 6059 | 5378 | 58° | 6090 | 3233 |
| 29° | 6060 | 5327 | 59° | 6091 | 3142 |
| 30° | 6061 | 5275 | 60° | 6092 | 3051 |

# TABLE XXVII.—TRIGONOMETRIC AND MISCELLANEOUS FORMULAS.

## TRIGONOMETRIC FORMULAS.

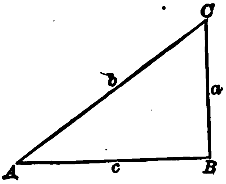

FIG. 98.

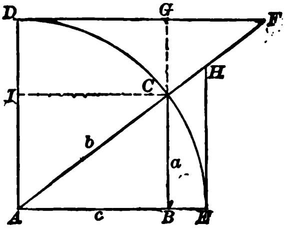

FIG. 99.

In Fig 99, let $DCE$ be the arc of a quadrant, $ABC$ a right triangle, the angle $BAC$ subtended by the arc $CE = A$, and consider the radius $AC =$ unity. Then

$BC = \sin A.$ $AF = \operatorname{cosec} A.$
$AB = \cos A.$ $BE = \operatorname{versin} A.$
$HE = \tan A.$ $DI = \operatorname{coversin} A.$
$DF = \cot A.$ $CH = \operatorname{exsec} A.$
$AH = \sec A.$ $CF = \operatorname{coexsec} A.$

Using the small letters $a$, $b$, $c$, to represent the sides of a right triangle in Fig. 98 or 99, we may write

$$\sin A = \frac{a}{b}; \quad \operatorname{cosec} A = \frac{b}{a}; \quad \therefore \sin A = \frac{1}{\operatorname{cosec} A}.$$

$$\cos A = \frac{c}{b}; \quad \sec A = \frac{b}{c}; \quad \therefore \cos A = \frac{1}{\sec A}.$$

$$\tan A = \frac{a}{c}; \quad \cot A = \frac{c}{a}; \quad \therefore \tan A = \frac{1}{\cot A}.$$

## TABLE XXVII.—TRIGONOMETRIC AND MISCELLANEOUS FORMULAS.

### SOLUTION OF RIGHT TRIANGLES.

| Required. | Given. | Formulas. |
|---|---|---|
| $A, C, c$ | $a, b$ | $\sin A = \cos C = \frac{a}{b}$; $c = \sqrt{(b+a)(b-a)}$. |
| $A, C, b$ | $a, c$ | $\tan A = \cot B = \frac{a}{c}$; $b = \sqrt{a^2 + c^2}$. |
| $C, b, c$ | $A, a$ | $C = 90° - A$; $c = a \cot A$; $b = a \operatorname{cosec} A$. |
| $C, a, c$ | $A, b$ | $C = 90° - A$; $a = b \sin A$; $c = b \operatorname{cosin} A$. |
| $C, a, b$ | $A, c$ | $C = 90° - A$; $a = c \tan A$; $b = c \sec A$. |

### SOLUTION OF OBLIQUE TRIANGLES.

| Required. | Given. | Formulas. |
|---|---|---|
| $b$ | $A, B, a$ | $b = \frac{a \sin B}{\sin A}$ |
| $B$ | $A, a, b$ | $\sin B = \frac{b \sin A}{a}$ |
| $\frac{1}{2}(A + B)$ | $a, b, C$ | $\frac{1}{2}(A + B) = \frac{1}{2}(180 - C)$ |
| $\frac{1}{2}(A - B)$ | | $\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$ |
| $A$ | | $A = \frac{1}{2}(A + B) + \frac{1}{2}(A - B)$ |
| $B$ | | $B = \frac{1}{2}(A + B) - \frac{1}{2}(A - B)$ |
| $A$ | $a, b, c$ | If $s = \frac{1}{2}(a + b + c)$, $\sin \frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{bc}}$ |
| | | $\cos \frac{1}{2}A = \sqrt{\frac{s(s-a)}{bc}}$, |
| | | $\tan \frac{1}{2}A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$ |
| | | $\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$ |
| Area | | $\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$ |
| Area | $A, b, c$ | $\text{Area} = \frac{1}{2} bc \sin A$ |
| Area | $A, B, c$ | $\text{Area} = \frac{c^2 \sin A \sin B}{2 \sin(A + B)}$ |

# TABLE XXVII.—TRIGONOMETRIC AND MISCELLANEO FORMULAS.

## GENERAL FORMULAS.

$$\sin A = \sqrt{1 - \cos^2 A} = \tan A \cos A.$$

$$\sin A = 2 \sin \tfrac{1}{2} A \cos \tfrac{1}{2} A.$$

$$\sin A = \frac{1}{\operatorname{cosec} A} = \sqrt{\tfrac{1}{2}(1 - \cos 2A)}.$$

$$\cos A = \frac{1}{\sec A} = \sqrt{1 - \sin^2 A} = \cot A \sin A.$$

$$\cos A = 1 - 2 \sin^2 \tfrac{1}{2} A = 1 - \operatorname{vers} A.$$

$$\cos A = \sqrt{\tfrac{1}{2} + \tfrac{1}{2} \cos 2A} = \cos^2 \tfrac{1}{2} A - \sin^2 \tfrac{1}{2} A.$$

$$\tan A = \frac{\sin A}{\cos A} = \sqrt{\sec^2 A - 1}.$$

$$\tan A = \frac{\sqrt{1 - \cos^2 A}}{\cos A} = \frac{\sin 2A}{1 + \cos 2A}.$$

$$\tan A = \frac{1}{\cot A} = \frac{1 - \cos 2A}{\sin 2A}.$$

$$\cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A} = \sqrt{\operatorname{cosec}^2 A - 1}.$$

$$\cot A = \frac{\sin 2A}{1 - \cos 2A} = \frac{1 + \cos 2A}{\sin 2A}.$$

$$\sec A = \frac{1}{\cos A} = \text{the reciprocal of any expression for } \cos A.$$

$$\operatorname{cosec} A = \frac{1}{\sin A} = \text{the reciprocal of any expression for } \sin A.$$

$$\operatorname{vers} A = 1 - \cos A = 2 \sin^2 \tfrac{1}{2} A.$$

$$\operatorname{exsec} A = \sec A - 1 = \frac{\operatorname{vers} A}{\cos A}.$$

$$\sin \tfrac{1}{2} A = \sqrt{\frac{1 - \cos A}{2}} = \sqrt{\frac{\operatorname{vers} A}{2}}.$$

## TABLE XXVII.—TRIGONOMETRIC AND MISCELLANEOUS FORMULAS.

$$\cos\tfrac{1}{2}A = \sqrt{\frac{1+\cos A}{2}}.$$

$$\tan\tfrac{1}{2}A = \frac{\tan A}{1+\sec A} = \frac{1-\cos A}{\sin A} = \frac{\sin A}{1+\cos A}.$$

$$\cot\tfrac{1}{2}A = \frac{1+\cos A}{\sin A} = \frac{\sin A}{1-\cos A}.$$

$$\sin 2A = 2\sin A\cos A.$$

$$\cos 2A = \cos^2 A - \sin^2 A = 2\cos^2 A - 1.$$

$$\tan 2A = \frac{2\tan A}{1-\tan^2 A}.$$

$$\cot 2A = \frac{\cot^2 A - 1}{2\cot A}.$$

$$\sin(A \pm B) = \sin A\cos B \pm \cos A\sin B.$$

$$\cos(A \pm B) = \cos A\cos B \mp \sin A\sin B.$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A\tan B}.$$

$$A + \sin B = 2\sin\tfrac{1}{2}(A+B)\cos\tfrac{1}{2}(A-B).$$

$$\sin A - \sin B = 2\cos\tfrac{1}{2}(A+B)\sin\tfrac{1}{2}(A-B).$$

$$\cos A + \cos B = 2\cos\tfrac{1}{2}(A+B)\cos\tfrac{1}{2}(A-B).$$

$$\cos B - \cos A = 2\sin\tfrac{1}{2}(A+B)\sin\tfrac{1}{2}(A-B).$$

$$\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin(A+B)\sin(A-B).$$

$$\cos^2 A - \sin^2 B = \cos(A+B)\cos(A-B).$$

$$\tan A \pm \tan B = \frac{\sin(A \pm B)}{\cos A\cos B}.$$

$$\cot A \pm \cot B = \frac{\pm\sin(A \pm B)}{\sin A\sin B}.$$

# TABLE XXVII.—TRIGONOMETRIC AND MISCELLANEOUS FORMULAS.

## MISCELLANEOUS FORMULAS.

| Required. | Given. | Formulas. |
|---|---|---|
| *Area of* | | |
| Trapezoid | Parallel sides = $m$ and $n$<br>Perp. dist. bet. them = $p$ | $\frac{p}{2}(m+n)$ |
| Regular Polygon | Length of side = $l$<br>Number of sides = $n$ | $\frac{nl^2}{4}\cot\frac{180^\circ}{n}$ |
| Circle | Radius = $r$ | $\pi r^2$ [$\pi = 3.1416$] |
| Ellipse | Semi-axes = $a$ and $b$ | $\pi ab$ |
| Parabola | Base = $b$, height = $h$ | $\frac{2}{3}bh$ |
| *Surface of* | | |
| Cone | Radius of base = $r$<br>Slant height = $s$ | $\pi rs$ |
| Cylinder | Radius = $r$, height = $h$ | $2\pi rh$ |
| Sphere | Radius = $r$ | $4\pi r^2$ |
| Zone | Height = $h$<br>Radius of its sphere = $r$ | $2\pi rh$ |
| *Volume of* | | |
| Prism or cylinder | Area of base = $b$<br>Height = $h$ | $bh$ |
| Pyramid or cone | Area of base = $b$<br>Height = $h$ | $\frac{bh}{3}$ |
| Frustum of | | |
| Pyramid or cone | Area of bases = $b$ and $b'$<br>Height = $h$ | $\frac{h}{3}(b + b' + \sqrt{bb'}$ |
| Sphere | Radius = $r$ | $\frac{4}{3}\pi r^3$ |

## Square Roots and Cube Roots of Numbers from .1 to 28.

No errors.

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Sq. Rt. | C. Rt. | No. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|---|
| .1 | .01 | .001 | .316 | .464 | .7 | 2.387 | 1.786 | .4 | 3.661 | 2.375 |
| .15 | .0225 | .0034 | .387 | .531 | .8 | 2.408 | 1.797 | .6 | 3.688 | 2.387 |
| .2 | .04 | .008 | .447 | .585 | .9 | 2.429 | 1.807 | .8 | 3.715 | 2.399 |
| .25 | .0625 | .0156 | .500 | .630 | 6. | 2.449 | 1.817 | 14. | 3.742 | 2.410 |
| .3 | .09 | .027 | .548 | .669 | .1 | 2.470 | 1.827 | .2 | 3.768 | 2.422 |
| .35 | .1225 | .0429 | .592 | .705 | .2 | 2.490 | 1.837 | .4 | 3.795 | 2.433 |
| .4 | .16 | .064 | .633 | .737 | .3 | 2.510 | 1.847 | .6 | 3.821 | 2.444 |
| .45 | .2025 | .0911 | .671 | .766 | .4 | 2.530 | 1.857 | .8 | 3.847 | 2.455 |
| .5 | .25 | .125 | .707 | .794 | .5 | 2.550 | 1.866 | 15. | 3.873 | 2.466 |
| .55 | .3025 | .1664 | .742 | .819 | .6 | 2.569 | 1.876 | .2 | 3.899 | 2.477 |
| .6 | .36 | .216 | .775 | .843 | .7 | 2.588 | 1.885 | .4 | 3.924 | 2.488 |
| .65 | .4225 | .2746 | .806 | .866 | .8 | 2.608 | 1.895 | .6 | 3.950 | 2.499 |
| .7 | .49 | .343 | .837 | .888 | .9 | 2.627 | 1.904 | .8 | 3.975 | 2.509 |
| .75 | .5625 | .4219 | .866 | .909 | 7. | 2.646 | 1.913 | 16. | 4. | 2.520 |
| .8 | .64 | .512 | .894 | .928 | .1 | 2.665 | 1.922 | .2 | 4.025 | 2.530 |
| .85 | .7225 | .6141 | .922 | .947 | .2 | 2.683 | 1.931 | .4 | 4.050 | 2.541 |
| .9 | .81 | .729 | .949 | .965 | .3 | 2.702 | 1.940 | .6 | 4.074 | 2.551 |
| .95 | .9025 | .8574 | .975 | .983 | .4 | 2.720 | 1.949 | .8 | 4.099 | 2.561 |
| 1. | 1.000 | 1.000 | 1.000 | 1.000 | .5 | 2.739 | 1.957 | 17. | 4.123 | 2.571 |
| .05 | 1.103 | 1.158 | 1.025 | 1.016 | .6 | 2.757 | 1.966 | .2 | 4.147 | 2.581 |
| 1.1 | 1.210 | 1.331 | 1.049 | 1.032 | .7 | 2.775 | 1.975 | .4 | 4.171 | 2.591 |
| .15 | 1.323 | 1.521 | 1.072 | 1.048 | .8 | 2.793 | 1.983 | .6 | 4.195 | 2.601 |
| 1.2 | 1.440 | 1.728 | 1.095 | 1.063 | .9 | 2.811 | 1.992 | .8 | 4.219 | 2.611 |
| .25 | 1.563 | 1.953 | 1.118 | 1.077 | 8. | 2.828 | 2.000 | 18. | 4.243 | 2.621 |
| 1.3 | 1.690 | 2.197 | 1.140 | 1.091 | .1 | 2.846 | 2.008 | .2 | 4.266 | 2.630 |
| .35 | 1.823 | 2.460 | 1.162 | 1.105 | .2 | 2.864 | 2.017 | .4 | 4.290 | 2.640 |
| 1.4 | 1.960 | 2.744 | 1.183 | 1.119 | .3 | 2.881 | 2.025 | .6 | 4.313 | 2.650 |
| .45 | 2.103 | 3.049 | 1.204 | 1.132 | .4 | 2.898 | 2.033 | .8 | 4.336 | 2.659 |
| 1.5 | 2.250 | 3.375 | 1.225 | 1.145 | .5 | 2.915 | 2.041 | 19. | 4.359 | 2.668 |
| .55 | 2.403 | 3.724 | 1.245 | 1.157 | .6 | 2.933 | 2.049 | .2 | 4.382 | 2.678 |
| 1.6 | 2.560 | 4.096 | 1.265 | 1.170 | .7 | 2.950 | 2.057 | .4 | 4.405 | 2.687 |
| .65 | 2.723 | 4.492 | 1.285 | 1.182 | .8 | 2.966 | 2.065 | .6 | 4.427 | 2.696 |
| 1.7 | 2.890 | 4.913 | 1.304 | 1.193 | .9 | 2.983 | 2.072 | .8 | 4.450 | 2.705 |
| .75 | 3.063 | 5.359 | 1.323 | 1.205 | 9. | 3. | 2.080 | 20. | 4.472 | 2.714 |
| 1.8 | 3.240 | 5.832 | 1.342 | 1.216 | .1 | 3.017 | 2.088 | .2 | 4.494 | 2.723 |
| .85 | 3.423 | 6.332 | 1.360 | 1.228 | .2 | 3.033 | 2.095 | .4 | 4.517 | 2.732 |
| 1.9 | 3.610 | 6.859 | 1.378 | 1.239 | .3 | 3.050 | 2.103 | .6 | 4.539 | 2.741 |
| .95 | 3.803 | 7.415 | 1.396 | 1.249 | .4 | 3.066 | 2.110 | .8 | 4.561 | 2.750 |
| 2. | 4.000 | 8.000 | 1.414 | 1.260 | .5 | 3.082 | 2.118 | 21. | 4.583 | 2.759 |
| .1 | 4.410 | 9.261 | 1.449 | 1.281 | .6 | 3.098 | 2.125 | .2 | 4.604 | 2.768 |
| .2 | 4.840 | 10.65 | 1.483 | 1.301 | .7 | 3.114 | 2.133 | .4 | 4.626 | 2.776 |
| .3 | 5.290 | 12.17 | 1.517 | 1.320 | .8 | 3.130 | 2.140 | .6 | 4.648 | 2.785 |
| .4 | 5.760 | 13.82 | 1.549 | 1.339 | .9 | 3.146 | 2.147 | .8 | 4.669 | 2.794 |
| .5 | 6.250 | 15.63 | 1.581 | 1.357 | 10. | 3.162 | 2.154 | 22. | 4.690 | 2.802 |
| .6 | 6.760 | 17.58 | 1.612 | 1.375 | .1 | 3.178 | 2.162 | .2 | 4.712 | 2.810 |
| .7 | 7.290 | 19.68 | 1.643 | 1.392 | .2 | 3.194 | 2.169 | .4 | 4.733 | 2.819 |
| .8 | 7.840 | 21.95 | 1.673 | 1.409 | .3 | 3.209 | 2.176 | .6 | 4.754 | 2.827 |
| .9 | 8.410 | 24.39 | 1.703 | 1.426 | .4 | 3.225 | 2.183 | .8 | 4.775 | 2.836 |
| 3. | 9. | 27. | 1.732 | 1.442 | .5 | 3.240 | 2.190 | 23. | 4.796 | 2.844 |
| .1 | 9.61 | 29.79 | 1.761 | 1.458 | .6 | 3.256 | 2.197 | .2 | 4.817 | 2.852 |
| .2 | 10.24 | 32.77 | 1.789 | 1.474 | .7 | 3.271 | 2.204 | .4 | 4.837 | 2.860 |
| .3 | 10.89 | 35.94 | 1.817 | 1.489 | .8 | 3.286 | 2.210 | .6 | 4.858 | 2.868 |
| .4 | 11.56 | 39.30 | 1.844 | 1.504 | .9 | 3.302 | 2.217 | .8 | 4.879 | 2.876 |
| .5 | 12.25 | 42.88 | 1.871 | 1.518 | 11. | 3.317 | 2.224 | 24. | 4.899 | 2.884 |
| .6 | 12.96 | 46.66 | 1.897 | 1.533 | .1 | 3.332 | 2.231 | .2 | 4.919 | 2.892 |
| .7 | 13.69 | 50.65 | 1.924 | 1.547 | .2 | 3.347 | 2.237 | .4 | 4.940 | 2.900 |
| .8 | 14.44 | 54.87 | 1.949 | 1.560 | .3 | 3.362 | 2.244 | .6 | 4.960 | 2.908 |
| .9 | 15.21 | 59.32 | 1.975 | 1.574 | .4 | 3.376 | 2.251 | .8 | 4.980 | 2.916 |
| 4. | 16. | 64. | 2. | 1.587 | .5 | 3.391 | 2.257 | 25. | 5. | 2.924 |
| .1 | 16.81 | 68.92 | 2.025 | 1.601 | .6 | 3.406 | 2.264 | .2 | 5.020 | 2.932 |
| .2 | 17.64 | 74.09 | 2.049 | 1.613 | .7 | 3.421 | 2.270 | .4 | 5.040 | 2.940 |
| .3 | 18.49 | 79.51 | 2.074 | 1.626 | .8 | 3.435 | 2.277 | .6 | 5.060 | 2.947 |
| .4 | 19.36 | 85.18 | 2.098 | 1.639 | .9 | 3.450 | 2.283 | .8 | 5.079 | 2.955 |
| .5 | 20.25 | 91.13 | 2.121 | 1.651 | 12. | 3.464 | 2.289 | 26. | 5.099 | 2.962 |
| .6 | 21.16 | 97.34 | 2.145 | 1.663 | .1 | 3.479 | 2.296 | .2 | 5.119 | 2.970 |
| .7 | 22.09 | 103.8 | 2.168 | 1.675 | .2 | 3.493 | 2.302 | .4 | 5.138 | 2.978 |
| .8 | 23.04 | 110.6 | 2.191 | 1.687 | .3 | 3.507 | 2.308 | .6 | 5.158 | 2.985 |
| .9 | 24.01 | 117.6 | 2.214 | 1.698 | .4 | 3.521 | 2.315 | .8 | 5.177 | 2.993 |
| 5. | 25. | 125. | 2.236 | 1.710 | .5 | 3.536 | 2.321 | 27. | 5.196 | 3.000 |
| .1 | 26.01 | 132.7 | 2.258 | 1.721 | .6 | 3.550 | 2.327 | .2 | 5.215 | 3.007 |
| .2 | 27.04 | 140.6 | 2.280 | 1.732 | .7 | 3.564 | 2.333 | .4 | 5.235 | 3.015 |
| .3 | 28.09 | 148.9 | 2.302 | 1.744 | .8 | 3.578 | 2.339 | .6 | 5.254 | 3.023 |
| .4 | 29.16 | 157.5 | 2.324 | 1.754 | .9 | 3.592 | 2.345 | .8 | 5.273 | 3.029 |
| .5 | 30.25 | 166.4 | 2.345 | 1.765 | 13. | 3.606 | 2.351 | 28. | 5.292 | 3.037 |
| .6 | 31.36 | 175.6 | 2.366 | 1.776 | .2 | 3.633 | 2.363 | .2 | 5.310 | 3.044 |

## TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000.

REMARK ON THE FOLLOWING TABLE. Wherever the effect of a fifth decimal in the roots would be to add 1 to the fourth and final decimal in the table, the addition has been made. No errors.

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1.0000 | 1.0000 | 61 | 3721 | 226981 | 7.8102 | 3.9365 |
| 2 | 4 | 8 | 1.4142 | 1.2599 | 62 | 3844 | 238328 | 7.8740 | 3.9579 |
| 3 | 9 | 27 | 1.7321 | 1.4422 | 63 | 3969 | 250047 | 7.9373 | 3.9791 |
| 4 | 16 | 64 | 2.0000 | 1.5874 | 64 | 4096 | 262144 | 8.0000 | 4. |
| 5 | 25 | 125 | 2.2361 | 1.7100 | 65 | 4225 | 274625 | 8.0623 | 4.0207 |
| 6 | 36 | 216 | 2.4495 | 1.8171 | 66 | 4356 | 287496 | 8.1240 | 4.0412 |
| 7 | 49 | 343 | 2.6458 | 1.9129 | 67 | 4489 | 300763 | 8.1854 | 4.0615 |
| 8 | 64 | 512 | 2.8284 | 2.0000 | 68 | 4624 | 314432 | 8.2462 | 4.0817 |
| 9 | 81 | 729 | 3.0000 | 2.0801 | 69 | 4761 | 328509 | 8.3066 | 4.1016 |
| 10 | 100 | 1000 | 3.1623 | 2.1544 | 70 | 4900 | 343000 | 8.3666 | 4.1213 |
| 11 | 121 | 1331 | 3.3166 | 2.2240 | 71 | 5041 | 357911 | 8.4261 | 4.1408 |
| 12 | 144 | 1728 | 3.4641 | 2.2894 | 72 | 5184 | 373248 | 8.4853 | 4.1602 |
| 13 | 169 | 2197 | 3.6056 | 2.3513 | 73 | 5329 | 389017 | 8.5440 | 4.1793 |
| 14 | 196 | 2744 | 3.7417 | 2.4101 | 74 | 5476 | 405224 | 8.6023 | 4.1983 |
| 15 | 225 | 3375 | 3.8730 | 2.4662 | 75 | 5625 | 421875 | 8.6603 | 4.2172 |
| 16 | 256 | 4096 | 4.0000 | 2.5198 | 76 | 5776 | 438976 | 8.7178 | 4.2358 |
| 17 | 289 | 4913 | 4.1231 | 2.5713 | 77 | 5929 | 456533 | 8.7750 | 4.2543 |
| 18 | 324 | 5832 | 4.2426 | 2.6207 | 78 | 6084 | 474552 | 8.8318 | 4.2727 |
| 19 | 361 | 6859 | 4.3589 | 2.6684 | 79 | 6241 | 493039 | 8.8882 | 4.2908 |
| 20 | 400 | 8000 | 4.4721 | 2.7144 | 80 | 6400 | 512000 | 8.9443 | 4.3089 |
| 21 | 441 | 9261 | 4.5826 | 2.7589 | 81 | 6561 | 531441 | 9. | 4.3267 |
| 22 | 484 | 10648 | 4.6904 | 2.8020 | 82 | 6724 | 551368 | 9.0554 | 4.3445 |
| 23 | 529 | 12167 | 4.7958 | 2.8439 | 83 | 6889 | 571787 | 9.1104 | 4.3621 |
| 24 | 576 | 13824 | 4.8990 | 2.8845 | 84 | 7056 | 592704 | 9.1652 | 4.3795 |
| 25 | 625 | 15625 | 5.0000 | 2.9240 | 85 | 7225 | 614125 | 9.2195 | 4.3968 |
| 26 | 676 | 17576 | 5.0990 | 2.9625 | 86 | 7396 | 636056 | 9.2736 | 4.4140 |
| 27 | 729 | 19683 | 5.1962 | 3.0000 | 87 | 7569 | 658503 | 9.3274 | 4.4310 |
| 28 | 784 | 21952 | 5.2915 | 3.0366 | 88 | 7744 | 681472 | 9.3808 | 4.4480 |
| 29 | 841 | 24389 | 5.3852 | 3.0723 | 89 | 7921 | 704969 | 9.4340 | 4.4647 |
| 30 | 900 | 27000 | 5.4772 | 3.1072 | 90 | 8100 | 729000 | 9.4868 | 4.4814 |
| 31 | 961 | 29791 | 5.5678 | 3.1414 | 91 | 8281 | 753571 | 9.5394 | 4.4979 |
| 32 | 1024 | 32768 | 5.6569 | 3.1748 | 92 | 8464 | 778688 | 9.5917 | 4.5144 |
| 33 | 1089 | 35937 | 5.7446 | 3.2075 | 93 | 8649 | 804357 | 9.6437 | 4.5307 |
| 34 | 1156 | 39304 | 5.8310 | 3.2396 | 94 | 8836 | 830584 | 9.6954 | 4.5468 |
| 35 | 1225 | 42875 | 5.9161 | 3.2711 | 95 | 9025 | 857375 | 9.7468 | 4.5629 |
| 36 | 1296 | 46656 | 6.0000 | 3.3019 | 96 | 9216 | 884736 | 9.7980 | 4.5789 |
| 37 | 1369 | 50653 | 6.0828 | 3.3322 | 97 | 9409 | 912673 | 9.8489 | 4.5947 |
| 38 | 1444 | 54872 | 6.1644 | 3.3620 | 98 | 9604 | 941192 | 9.8995 | 4.6104 |
| 39 | 1521 | 59319 | 6.2450 | 3.3912 | 99 | 9801 | 970299 | 9.9499 | 4.6261 |
| 40 | 1600 | 64000 | 6.3246 | 3.4200 | 100 | 10000 | 1000000 | 10. | 4.6416 |
| 41 | 1681 | 68921 | 6.4031 | 3.4482 | 101 | 10201 | 1030301 | 10.0499 | 4.6570 |
| 42 | 1764 | 74088 | 6.4807 | 3.4760 | 102 | 10404 | 1061208 | 10.0995 | 4.6723 |
| 43 | 1849 | 79507 | 6.5574 | 3.5034 | 103 | 10609 | 1092727 | 10.1489 | 4.6875 |
| 44 | 1936 | 85184 | 6.6332 | 3.5303 | 104 | 10816 | 1124864 | 10.1980 | 4.7027 |
| 45 | 2025 | 91125 | 6.7082 | 3.5569 | 105 | 11025 | 1157625 | 10.2470 | 4.7177 |
| 46 | 2116 | 97336 | 6.7823 | 3.5830 | 106 | 11236 | 1191016 | 10.2956 | 4.7326 |
| 47 | 2209 | 103823 | 6.8557 | 3.6088 | 107 | 11449 | 1225043 | 10.3441 | 4.7475 |
| 48 | 2304 | 110592 | 6.9282 | 3.6342 | 108 | 11664 | 1259712 | 10.3923 | 4.7622 |
| 49 | 2401 | 117649 | 7.0000 | 3.6593 | 109 | 11881 | 1295029 | 10.4403 | 4.7769 |
| 50 | 2500 | 125000 | 7.0711 | 3.6840 | 110 | 12100 | 1331000 | 10.4881 | 4.7914 |
| 51 | 2601 | 132651 | 7.1414 | 3.7084 | 111 | 12321 | 1367631 | 10.5357 | 4.8059 |
| 52 | 2704 | 140608 | 7.2111 | 3.7325 | 112 | 12544 | 1404928 | 10.5830 | 4.8203 |
| 53 | 2809 | 148877 | 7.2801 | 3.7563 | 113 | 12769 | 1442897 | 10.6301 | 4.8346 |
| 54 | 2916 | 157464 | 7.3485 | 3.7798 | 114 | 12996 | 1481544 | 10.6771 | 4.8488 |
| 55 | 3025 | 166375 | 7.4162 | 3.8030 | 115 | 13225 | 1520875 | 10.7238 | 4.8629 |
| 56 | 3136 | 175616 | 7.4833 | 3.8259 | 116 | 13456 | 1560896 | 10.7703 | 4.8770 |
| 57 | 3249 | 185193 | 7.5498 | 3.8485 | 117 | 13689 | 1601613 | 10.8167 | 4.8910 |
| 58 | 3364 | 195112 | 7.6158 | 3.8709 | 118 | 13924 | 1643032 | 10.8628 | 4.9049 |
| 59 | 3481 | 205379 | 7.6811 | 3.8930 | 119 | 14161 | 1685159 | 10.9087 | 4.9187 |
| 60 | 3600 | 216000 | 7.7460 | 3.9149 | 120 | 14400 | 1728000 | 10.9545 | 4.9324 |

## TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000—(CONTINUED.)

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 121 | 14641 | 1771561 | 11. | 4.9461 | 186 | 34596 | 6434856 | 13.6382 | 5.7083 |
| 122 | 14884 | 1815848 | 11.0454 | 4.9597 | 187 | 34969 | 6539203 | 13.6748 | 5.7185 |
| 123 | 15129 | 1860867 | 11.0905 | 4.9732 | 188 | 35344 | 6644672 | 13.7113 | 5.7287 |
| 124 | 15376 | 1906624 | 11.1355 | 4.9866 | 189 | 35721 | 6751269 | 13.7477 | 5.7388 |
| 125 | 15625 | 1953125 | 11.1803 | 5. | 190 | 36100 | 6859000 | 13.7840 | 5.7489 |
| 126 | 15876 | 2000376 | 11.2250 | 5.0133 | 191 | 36481 | 6967871 | 13.8203 | 5.7590 |
| 127 | 16129 | 2048383 | 11.2694 | 5.0265 | 192 | 36864 | 7077888 | 13.8564 | 5.7690 |
| 128 | 16384 | 2097152 | 11.3137 | 5.0397 | 193 | 37249 | 7189057 | 13.8924 | 5.7790 |
| 129 | 16641 | 2146689 | 11.3578 | 5.0528 | 194 | 37636 | 7301384 | 13.9284 | 5.7890 |
| 130 | 16900 | 2197000 | 11.4018 | 5.0658 | 195 | 38025 | 7414875 | 13.9642 | 5.7989 |
| 131 | 17161 | 2248091 | 11.4455 | 5.0788 | 196 | 38416 | 7529536 | 14. | 5.8088 |
| 132 | 17424 | 2299968 | 11.4891 | 5.0916 | 197 | 38809 | 7645373 | 14.0357 | 5.8186 |
| 133 | 17689 | 2352637 | 11.5326 | 5.1045 | 198 | 39204 | 7762392 | 14.0712 | 5.8285 |
| 134 | 17956 | 2406104 | 11.5758 | 5.1172 | 199 | 39601 | 7880599 | 14.1067 | 5.8383 |
| 135 | 18225 | 2460375 | 11.6190 | 5.1299 | 200 | 40000 | 8000000 | 14.1421 | 5.8480 |
| 136 | 18496 | 2515456 | 11.6619 | 5.1426 | 201 | 40401 | 8120601 | 14.1774 | 5.8578 |
| 137 | 18769 | 2571353 | 11.7047 | 5.1551 | 202 | 40804 | 8242408 | 14.2127 | 5.8675 |
| 138 | 19044 | 2628072 | 11.7473 | 5.1676 | 203 | 41209 | 8365427 | 14.2478 | 5.8771 |
| 139 | 19321 | 2685619 | 11.7898 | 5.1801 | 204 | 41616 | 8489664 | 14.2829 | 5.8868 |
| 140 | 19600 | 2744000 | 11.8322 | 5.1925 | 205 | 42025 | 8615125 | 14.3178 | 5.8964 |
| 141 | 19881 | 2803221 | 11.8743 | 5.2048 | 206 | 42436 | 8741816 | 14.3527 | 5.9059 |
| 142 | 20164 | 2863288 | 11.9164 | 5.2171 | 207 | 42849 | 8869743 | 14.3875 | 5.9155 |
| 143 | 20449 | 2924207 | 11.9583 | 5.2293 | 208 | 43264 | 8998912 | 14.4222 | 5.9250 |
| 144 | 20736 | 2985984 | 12. | 5.2415 | 209 | 43681 | 9129329 | 14.4568 | 5.9345 |
| 145 | 21025 | 3048625 | 12.0416 | 5.2536 | 210 | 44100 | 9261000 | 14.4914 | 5.9439 |
| 146 | 21316 | 3112136 | 12.0830 | 5.2656 | 211 | 44521 | 9393931 | 14.5258 | 5.9533 |
| 147 | 21609 | 3176523 | 12.1244 | 5.2776 | 212 | 44944 | 9528128 | 14.5602 | 5.9627 |
| 148 | 21904 | 3241792 | 12.1655 | 5.2896 | 213 | 45369 | 9663597 | 14.5945 | 5.9721 |
| 149 | 22201 | 3307949 | 12.2066 | 5.3015 | 214 | 45796 | 9800344 | 14.6287 | 5.9814 |
| 150 | 22500 | 3375000 | 12.2474 | 5.3133 | 215 | 46225 | 9938375 | 14.6629 | 5.9907 |
| 151 | 22801 | 3442951 | 12.2882 | 5.3251 | 216 | 46656 | 10077696 | 14.6969 | 6. |
| 152 | 23104 | 3511808 | 12.3288 | 5.3368 | 217 | 47089 | 10218313 | 14.7309 | 6.0092 |
| 153 | 23409 | 3581577 | 12.3693 | 5.3485 | 218 | 47524 | 10360232 | 14.7648 | 6.0185 |
| 154 | 23716 | 3652264 | 12.4097 | 5.3601 | 219 | 47961 | 10503459 | 14.7986 | 6.0277 |
| 155 | 24025 | 3723875 | 12.4499 | 5.3717 | 220 | 48400 | 10648000 | 14.8324 | 6.0368 |
| 156 | 24336 | 3796416 | 12.4900 | 5.3832 | 221 | 48841 | 10793861 | 14.8661 | 6.0459 |
| 157 | 24649 | 3869893 | 12.5300 | 5.3947 | 222 | 49284 | 10941048 | 14.8997 | 6.0550 |
| 158 | 24964 | 3944312 | 12.5698 | 5.4061 | 223 | 49729 | 11089567 | 14.9332 | 6.0641 |
| 159 | 25281 | 4019679 | 12.6095 | 5.4175 | 224 | 50176 | 11239424 | 14.9666 | 6.0732 |
| 160 | 25600 | 4096000 | 12.6491 | 5.4288 | 225 | 50625 | 11390625 | 15. | 6.0822 |
| 161 | 25921 | 4173281 | 12.6886 | 5.4401 | 226 | 51076 | 11543176 | 15.0333 | 6.0912 |
| 162 | 26244 | 4251528 | 12.7279 | 5.4514 | 227 | 51529 | 11697083 | 15.0665 | 6.1002 |
| 163 | 26569 | 4330747 | 12.7671 | 5.4626 | 228 | 51984 | 11852352 | 15.0997 | 6.1091 |
| 164 | 26896 | 4410944 | 12.8062 | 5.4737 | 229 | 52441 | 12008989 | 15.1327 | 6.1180 |
| 165 | 27225 | 4492125 | 12.8452 | 5.4848 | 230 | 52900 | 12167000 | 15.1658 | 6.1269 |
| 166 | 27556 | 4574296 | 12.8841 | 5.4959 | 231 | 53361 | 12326391 | 15.1987 | 6.1358 |
| 167 | 27889 | 4657463 | 12.9228 | 5.5069 | 232 | 53824 | 12487168 | 15.2315 | 6.1446 |
| 168 | 28224 | 4741632 | 12.9615 | 5.5178 | 233 | 54289 | 12649337 | 15.2643 | 6.1534 |
| 169 | 28561 | 4826809 | 13. | 5.5288 | 234 | 54756 | 12812904 | 15.2971 | 6.1622 |
| 170 | 28900 | 4913000 | 13.0384 | 5.5397 | 235 | 55225 | 12977875 | 15.3297 | 6.1710 |
| 171 | 29241 | 5000211 | 13.0767 | 5.5505 | 236 | 55696 | 13144256 | 15.3623 | 6.1797 |
| 172 | 29584 | 5088448 | 13.1149 | 5.5613 | 237 | 56169 | 13312053 | 15.3948 | 6.1885 |
| 173 | 29929 | 5177717 | 13.1529 | 5.5721 | 238 | 56644 | 13481272 | 15.4272 | 6.1972 |
| 174 | 30276 | 5268024 | 13.1909 | 5.5828 | 239 | 57121 | 13651919 | 15.4596 | 6.2058 |
| 175 | 30625 | 5359375 | 13.2288 | 5.5934 | 240 | 57600 | 13824000 | 15.4919 | 6.2145 |
| 176 | 30976 | 5451776 | 13.2665 | 5.6041 | 241 | 58081 | 13997521 | 15.5242 | 6.2231 |
| 177 | 31329 | 5545233 | 13.3041 | 5.6147 | 242 | 58564 | 14172488 | 15.5563 | 6.2317 |
| 178 | 31684 | 5639752 | 13.3417 | 5.6252 | 243 | 59049 | 14348907 | 15.5885 | 6.2403 |
| 179 | 32041 | 5735339 | 13.3791 | 5.6357 | 244 | 59536 | 14526784 | 15.6205 | 6.2488 |
| 180 | 32400 | 5832000 | 13.4164 | 5.6462 | 245 | 60025 | 14706125 | 15.6525 | 6.2573 |
| 181 | 32761 | 5929741 | 13.4536 | 5.6567 | 246 | 60516 | 14886936 | 15.6844 | 6.2658 |
| 182 | 33124 | 6028568 | 13.4907 | 5.6671 | 247 | 61009 | 15069223 | 15.7162 | 6.2743 |
| 183 | 33489 | 6128487 | 13.5277 | 5.6774 | 248 | 61504 | 15252992 | 15.7480 | 6.2828 |
| 184 | 33856 | 6229504 | 13.5647 | 5.6877 | 249 | 62001 | 15438249 | 15.7797 | 6.2912 |
| 185 | 34225 | 6331625 | 13.6015 | 5.6980 | 250 | 62500 | 15625000 | 15.8114 | 6.2996 |

## TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000—(CONTINUED.)

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 251 | 63001 | 15813251 | 15.8430 | 6.3080 | 316 | 99856 | 31554496 | 17.7764 | 6.8113 |
| 252 | 63504 | 16003008 | 15.8745 | 6.3164 | 317 | 100489 | 31855013 | 17.8045 | 6.8185 |
| 253 | 64009 | 16194277 | 15.9060 | 6.3247 | 318 | 101124 | 32157432 | 17.8326 | 6.8256 |
| 254 | 64516 | 16387064 | 15.9374 | 6.3330 | 319 | 101761 | 32461759 | 17.8606 | 6.8328 |
| 255 | 65025 | 16581375 | 15.9687 | 6.3413 | 320 | 102400 | 32768000 | 17.8885 | 6.8399 |
| 256 | 65536 | 16777216 | 16. | 6.3496 | 321 | 103041 | 33076161 | 17.9165 | 6.8470 |
| 257 | 66049 | 16974593 | 16.0312 | 6.3579 | 322 | 103684 | 33386248 | 17.9444 | 6.8541 |
| 258 | 66564 | 17173512 | 16.0624 | 6.3661 | 323 | 104329 | 33698267 | 17.9722 | 6.8612 |
| 259 | 67081 | 17373979 | 16.0935 | 6.3743 | 324 | 104976 | 34012224 | 18. | 6.8683 |
| 260 | 67600 | 17576000 | 16.1245 | 6.3825 | 325 | 105625 | 34328125 | 18.0278 | 6.8753 |
| 261 | 68121 | 17779581 | 16.1555 | 6.3907 | 326 | 106276 | 34645976 | 18.0555 | 6.8824 |
| 262 | 68644 | 17984728 | 16.1864 | 6.3988 | 327 | 106929 | 34965783 | 18.0831 | 6.8894 |
| 263 | 69169 | 18191447 | 16.2173 | 6.4070 | 328 | 107584 | 35287552 | 18.1108 | 6.8964 |
| 264 | 69696 | 18399744 | 16.2481 | 6.4151 | 329 | 108241 | 35611289 | 18.1384 | 6.9034 |
| 265 | 70225 | 18609625 | 16.2788 | 6.4232 | 330 | 108900 | 35937000 | 18.1659 | 6.9104 |
| 266 | 70756 | 18821096 | 16.3095 | 6.4312 | 331 | 109561 | 36264691 | 18.1934 | 6.9174 |
| 267 | 71289 | 19034163 | 16.3401 | 6.4393 | 332 | 110224 | 36594368 | 18.2209 | 6.9244 |
| 268 | 71824 | 19248832 | 16.3707 | 6.4473 | 333 | 110889 | 36926037 | 18.2483 | 6.9313 |
| 269 | 72361 | 19465109 | 16.4012 | 6.4553 | 334 | 111556 | 37259704 | 18.2757 | 6.9382 |
| 270 | 72900 | 19683000 | 16.4317 | 6.4633 | 335 | 112225 | 37595375 | 18.3030 | 6.9451 |
| 271 | 73441 | 19902511 | 16.4621 | 6.4713 | 336 | 112896 | 37933056 | 18.3303 | 6.9521 |
| 272 | 73984 | 20123648 | 16.4924 | 6.4792 | 337 | 113569 | 38272753 | 18.3576 | 6.9589 |
| 273 | 74529 | 20346417 | 16.5227 | 6.4872 | 338 | 114244 | 38614472 | 18.3848 | 6.9658 |
| 274 | 75076 | 20570824 | 16.5529 | 6.4951 | 339 | 114921 | 38958219 | 18.4120 | 6.9727 |
| 275 | 75625 | 20796875 | 16.5831 | 6.5030 | 340 | 115600 | 39304000 | 18.4391 | 6.9795 |
| 276 | 76176 | 21024576 | 16.6132 | 6.5108 | 341 | 116281 | 39651821 | 18.4662 | 6.9864 |
| 277 | 76729 | 21253933 | 16.6433 | 6.5187 | 342 | 116964 | 40001688 | 18.4932 | 6.9932 |
| 278 | 77284 | 21484952 | 16.6733 | 6.5265 | 343 | 117649 | 40353607 | 18.5203 | 7. |
| 279 | 77841 | 21717639 | 16.7033 | 6.5343 | 344 | 118336 | 40707584 | 18.5472 | 7.0068 |
| 280 | 78400 | 21952000 | 16.7332 | 6.5421 | 345 | 119025 | 41063625 | 18.5742 | 7.0136 |
| 281 | 78961 | 22188041 | 16.7631 | 6.5499 | 346 | 119716 | 41421736 | 18.6011 | 7.0203 |
| 282 | 79524 | 22425768 | 16.7929 | 6.5577 | 347 | 120409 | 41781923 | 18.6279 | 7.0271 |
| 283 | 80089 | 22665187 | 16.8226 | 6.5654 | 348 | 121104 | 42144192 | 18.6548 | 7.0338 |
| 284 | 80656 | 22906304 | 16.8523 | 6.5731 | 349 | 121801 | 42508549 | 18.6815 | 7.0406 |
| 285 | 81225 | 23149125 | 16.8819 | 6.5808 | 350 | 122500 | 42875000 | 18.7083 | 7.0473 |
| 286 | 81796 | 23393656 | 16.9115 | 6.5885 | 351 | 123201 | 43243551 | 18.7350 | 7.0540 |
| 287 | 82369 | 23639903 | 16.9411 | 6.5962 | 352 | 123904 | 43614208 | 18.7617 | 7.0607 |
| 288 | 82944 | 23887872 | 16.9706 | 6.6039 | 353 | 124609 | 43986977 | 18.7883 | 7.0674 |
| 289 | 83521 | 24137569 | 17. | 6.6115 | 354 | 125316 | 44361864 | 18.8149 | 7.0740 |
| 290 | 84100 | 24389000 | 17.0294 | 6.6191 | 355 | 126025 | 44738875 | 18.8414 | 7.0807 |
| 291 | 84681 | 24642171 | 17.0587 | 6.6267 | 356 | 126736 | 45118016 | 18.8680 | 7.0873 |
| 292 | 85264 | 24897088 | 17.0880 | 6.6343 | 357 | 127449 | 45499293 | 18.8944 | 7.0940 |
| 293 | 85849 | 25153757 | 17.1172 | 6.6419 | 358 | 128164 | 45882712 | 18.9209 | 7.1006 |
| 294 | 86436 | 25412184 | 17.1464 | 6.6494 | 359 | 128881 | 46268279 | 18.9473 | 7.1072 |
| 295 | 87025 | 25672375 | 17.1756 | 6.6569 | 360 | 129600 | 46656000 | 18.9737 | 7.1138 |
| 296 | 87616 | 25934336 | 17.2047 | 6.6644 | 361 | 130321 | 47045881 | 19. | 7.1204 |
| 297 | 88209 | 26198073 | 17.2337 | 6.6719 | 362 | 131044 | 47437928 | 19.0263 | 7.1269 |
| 298 | 88804 | 26463592 | 17.2627 | 6.6794 | 363 | 131769 | 47832147 | 19.0526 | 7.1335 |
| 299 | 89401 | 26730899 | 17.2916 | 6.6869 | 364 | 132496 | 48228544 | 19.0788 | 7.1400 |
| 300 | 90000 | 27000000 | 17.3205 | 6.6943 | 365 | 133225 | 48627125 | 19.1050 | 7.1466 |
| 301 | 90601 | 27270901 | 17.3494 | 6.7018 | 366 | 133956 | 49027896 | 19.1311 | 7.1531 |
| 302 | 91204 | 27543608 | 17.3781 | 6.7092 | 367 | 134689 | 49430863 | 19.1572 | 7.1596 |
| 303 | 91809 | 27818127 | 17.4069 | 6.7166 | 368 | 135424 | 49836032 | 19.1833 | 7.1661 |
| 304 | 92416 | 28094464 | 17.4356 | 6.7240 | 369 | 136161 | 50243409 | 19.2094 | 7.1726 |
| 305 | 93025 | 28372625 | 17.4642 | 6.7313 | 370 | 136900 | 50653000 | 19.2354 | 7.1791 |
| 306 | 93636 | 28652616 | 17.4929 | 6.7387 | 371 | 137641 | 51064811 | 19.2614 | 7.1855 |
| 307 | 94249 | 28934443 | 17.5214 | 6.7460 | 372 | 138384 | 51478848 | 19.2873 | 7.1920 |
| 308 | 94864 | 29218112 | 17.5499 | 6.7533 | 373 | 139129 | 51895117 | 19.3132 | 7.1984 |
| 309 | 95481 | 29503629 | 17.5784 | 6.7606 | 374 | 139876 | 52313624 | 19.3391 | 7.2048 |
| 310 | 96100 | 29791000 | 17.6068 | 6.7679 | 375 | 140625 | 52734375 | 19.3649 | 7.2112 |
| 311 | 96721 | 30080231 | 17.6352 | 6.7752 | 376 | 141376 | 53157376 | 19.3907 | 7.2177 |
| 312 | 97344 | 30371328 | 17.6635 | 6.7824 | 377 | 142129 | 53582633 | 19.4165 | 7.2240 |
| 313 | 97969 | 30664297 | 17.6918 | 6.7897 | 378 | 142884 | 54010152 | 19.4422 | 7.2304 |
| 314 | 98596 | 30959144 | 17.7200 | 6.7969 | 379 | 143641 | 54439939 | 19.4679 | 7.2368 |
| 315 | 99225 | 31255875 | 17.7482 | 6.8041 | 380 | 144400 | 54872000 | 19.4936 | 7.2432 |

**TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000**—(Continued.)

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 381 | 145161 | 55306341 | 19.5192 | 7.2495 | 446 | 198916 | 88716536 | 21.1187 | 7.6403 |
| 382 | 145924 | 55742968 | 19.5448 | 7.2558 | 447 | 199809 | 89314623 | 21.1424 | 7.6460 |
| 383 | 146689 | 56181887 | 19.5704 | 7.2622 | 448 | 200704 | 89915392 | 21.1660 | 7.6517 |
| 384 | 147456 | 56623104 | 19.5959 | 7.2685 | 449 | 201601 | 90518849 | 21.1896 | 7.6574 |
| 385 | 148225 | 57066625 | 19.6214 | 7.2748 | 450 | 202500 | 91125000 | 21.2132 | 7.6631 |
| 386 | 148996 | 57512456 | 19.6469 | 7.2811 | 451 | 203401 | 91733851 | 21.2368 | 7.6688 |
| 387 | 149769 | 57960603 | 19.6723 | 7.2874 | 452 | 204304 | 92345408 | 21.2603 | 7.6744 |
| 388 | 150544 | 58411072 | 19.6977 | 7.2936 | 453 | 205209 | 92959677 | 21.2838 | 7.6801 |
| 389 | 151321 | 58863869 | 19.7231 | 7.2999 | 454 | 206116 | 93576664 | 21.3073 | 7.6857 |
| 390 | 152100 | 59319000 | 19.7484 | 7.3061 | 455 | 207025 | 94196375 | 21.3307 | 7.6914 |
| 391 | 152881 | 59776471 | 19.7737 | 7.3124 | 456 | 207936 | 94818816 | 21.3542 | 7.6970 |
| 392 | 153664 | 60236288 | 19.7990 | 7.3186 | 457 | 208849 | 95443993 | 21.3776 | 7.7026 |
| 393 | 154449 | 60698457 | 19.8242 | 7.3248 | 458 | 209764 | 96071912 | 21.4009 | 7.7082 |
| 394 | 155236 | 61162984 | 19.8494 | 7.3310 | 459 | 210681 | 96702579 | 21.4243 | 7.7138 |
| 395 | 156025 | 61629875 | 19.8746 | 7.3372 | 460 | 211600 | 97336000 | 21.4476 | 7.7194 |
| 396 | 156816 | 62099136 | 19.8997 | 7.3434 | 461 | 212521 | 97972181 | 21.4709 | 7.7250 |
| 397 | 157609 | 62570773 | 19.9249 | 7.3496 | 462 | 213444 | 98611128 | 21.4942 | 7.7306 |
| 398 | 158404 | 63044792 | 19.9499 | 7.3558 | 463 | 214369 | 99252847 | 21.5174 | 7.7362 |
| 399 | 159201 | 63521199 | 19.9750 | 7.3619 | 464 | 215296 | 99897344 | 21.5407 | 7.7418 |
| 400 | 160000 | 64000000 | 20. | 7.3681 | 465 | 216225 | 100544625 | 21.5639 | 7.7473 |
| 401 | 160801 | 64481201 | 20.0250 | 7.3742 | 466 | 217156 | 101194696 | 21.5870 | 7.7529 |
| 402 | 161604 | 64964808 | 20.0499 | 7.3803 | 467 | 218089 | 101847563 | 21.6102 | 7.7584 |
| 403 | 162409 | 65450827 | 20.0749 | 7.3864 | 468 | 219024 | 102503232 | 21.6333 | 7.7639 |
| 404 | 163216 | 65939264 | 20.0998 | 7.3925 | 469 | 219961 | 103161709 | 21.6564 | 7.7695 |
| 405 | 164025 | 66430125 | 20.1246 | 7.3986 | 470 | 220900 | 103823000 | 21.6795 | 7.7750 |
| 406 | 164836 | 66923416 | 20.1494 | 7.4047 | 471 | 221841 | 104487111 | 21.7025 | 7.7805 |
| 407 | 165649 | 67419143 | 20.1742 | 7.4108 | 472 | 222784 | 105154048 | 21.7256 | 7.7860 |
| 408 | 166464 | 67917312 | 20.1990 | 7.4169 | 473 | 223729 | 105823817 | 21.7486 | 7.7915 |
| 409 | 167281 | 68417929 | 20.2237 | 7.4229 | 474 | 224676 | 106496424 | 21.7715 | 7.7970 |
| 410 | 168100 | 68921000 | 20.2485 | 7.4290 | 475 | 225625 | 107171875 | 21.7945 | 7.8025 |
| 411 | 168921 | 69426531 | 20.2731 | 7.4350 | 476 | 226576 | 107850176 | 21.8174 | 7.8079 |
| 412 | 169744 | 69934528 | 20.2978 | 7.4410 | 477 | 227529 | 108531333 | 21.8403 | 7.8134 |
| 413 | 170569 | 70444997 | 20.3224 | 7.4470 | 478 | 228484 | 109215352 | 21.8632 | 7.8188 |
| 414 | 171396 | 70957944 | 20.3470 | 7.4530 | 479 | 229441 | 109902239 | 21.8861 | 7.8243 |
| 415 | 172225 | 71473375 | 20.3715 | 7.4590 | 480 | 230400 | 110592000 | 21.9089 | 7.8297 |
| 416 | 173056 | 71991296 | 20.3961 | 7.4650 | 481 | 231361 | 111284641 | 21.9317 | 7.8352 |
| 417 | 173889 | 72511713 | 20.4206 | 7.4710 | 482 | 232324 | 111980168 | 21.9545 | 7.8406 |
| 418 | 174724 | 73034632 | 20.4450 | 7.4770 | 483 | 233289 | 112678587 | 21.9773 | 7.8460 |
| 419 | 175561 | 73560059 | 20.4695 | 7.4829 | 484 | 234256 | 113379904 | 22. | 7.8514 |
| 420 | 176400 | 74088000 | 20.4939 | 7.4889 | 485 | 235225 | 114084125 | 22.0227 | 7.8568 |
| 421 | 177241 | 74618461 | 20.5183 | 7.4948 | 486 | 236196 | 114791256 | 22.0454 | 7.8622 |
| 422 | 178084 | 75151448 | 20.5426 | 7.5007 | 487 | 237169 | 115501303 | 22.0681 | 7.8676 |
| 423 | 178929 | 75686967 | 20.5670 | 7.5067 | 488 | 238144 | 116214272 | 22.0907 | 7.8730 |
| 424 | 179776 | 76225024 | 20.5913 | 7.5126 | 489 | 239121 | 116930169 | 22.1133 | 7.8784 |
| 425 | 180625 | 76765625 | 20.6155 | 7.5185 | 490 | 240100 | 117649000 | 22.1359 | 7.8837 |
| 426 | 181476 | 77308776 | 20.6398 | 7.5244 | 491 | 241081 | 118370771 | 22.1585 | 7.8891 |
| 427 | 182329 | 77854483 | 20.6640 | 7.5302 | 492 | 242064 | 119095488 | 22.1811 | 7.8944 |
| 428 | 183184 | 78402752 | 20.6882 | 7.5361 | 493 | 243049 | 119823157 | 22.2036 | 7.8998 |
| 429 | 184041 | 78953589 | 20.7123 | 7.5420 | 494 | 244036 | 120553784 | 22.2261 | 7.9051 |
| 430 | 184900 | 79507000 | 20.7364 | 7.5478 | 495 | 245025 | 121287375 | 22.2486 | 7.9105 |
| 431 | 185761 | 80062991 | 20.7605 | 7.5537 | 496 | 246016 | 122023936 | 22.2711 | 7.9158 |
| 432 | 186624 | 80621568 | 20.7846 | 7.5595 | 497 | 247009 | 122763473 | 22.2935 | 7.9211 |
| 433 | 187489 | 81182737 | 20.8087 | 7.5654 | 498 | 248004 | 123505992 | 22.3159 | 7.9264 |
| 434 | 188356 | 81746504 | 20.8327 | 7.5712 | 499 | 249001 | 124251499 | 22.3383 | 7.9317 |
| 435 | 189225 | 82312875 | 20.8567 | 7.5770 | 500 | 250000 | 125000000 | 22.3607 | 7.9370 |
| 436 | 190096 | 82881856 | 20.8806 | 7.5828 | 501 | 251001 | 125751501 | 22.3830 | 7.9423 |
| 437 | 190969 | 83453453 | 20.9045 | 7.5886 | 502 | 252004 | 126506008 | 22.4054 | 7.9476 |
| 438 | 191844 | 84027672 | 20.9284 | 7.5944 | 503 | 253009 | 127263527 | 22.4277 | 7.9528 |
| 439 | 192721 | 84604519 | 20.9523 | 7.6001 | 504 | 254016 | 128024064 | 22.4499 | 7.9581 |
| 440 | 193600 | 85184000 | 20.9762 | 7.6059 | 505 | 255025 | 128787625 | 22.4722 | 7.9634 |
| 441 | 194481 | 85766121 | 21. | 7.6117 | 506 | 256036 | 129554216 | 22.4944 | 7.9686 |
| 442 | 195364 | 86350888 | 21.0238 | 7.6174 | 507 | 257049 | 130323843 | 22.5167 | 7.9739 |
| 443 | 196249 | 86938307 | 21.0476 | 7.6232 | 508 | 258064 | 131096512 | 22.5389 | 7.9791 |
| 444 | 197136 | 87528384 | 21.0713 | 7.6289 | 509 | 259081 | 131872229 | 22.5610 | 7.9843 |
| 445 | 198025 | 88121125 | 21.0950 | 7.6346 | 510 | 260100 | 132651000 | 22.5832 | 7.9896 |

## TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000—(CONTINUED.)

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 511 | 261121 | 133432831 | 22.6053 | 7.9948 | 576 | 331776 | 191102976 | 24. | 8.3203 |
| 512 | 262144 | 134217728 | 22.6274 | 8. | 577 | 332929 | 192100033 | 24.0208 | 8.3251 |
| 513 | 263169 | 135005697 | 22.6495 | 8.0052 | 578 | 334084 | 193100552 | 24.0416 | 8.3300 |
| 514 | 264196 | 135796744 | 22.6716 | 8.0104 | 579 | 335241 | 194104539 | 24.0624 | 8.3348 |
| 515 | 265225 | 136590875 | 22.6936 | 8.0156 | 580 | 336400 | 195112000 | 24.0832 | 8.3396 |
| 516 | 266256 | 137388096 | 22.7156 | 8.0208 | 581 | 337561 | 196122941 | 24.1039 | 8.3443 |
| 517 | 267289 | 138188413 | 22.7376 | 8.0260 | 582 | 338724 | 197137368 | 24.1247 | 8.3491 |
| 518 | 268324 | 138991832 | 22.7596 | 8.0311 | 583 | 339889 | 198155287 | 24.1454 | 8.3539 |
| 519 | 269361 | 139798359 | 22.7816 | 8.0363 | 584 | 341056 | 199176704 | 24.1661 | 8.3587 |
| 520 | 270400 | 140608000 | 22.8035 | 8.0415 | 585 | 342225 | 200201625 | 24.1868 | 8.3634 |
| 521 | 271441 | 141420761 | 22.8254 | 8.0466 | 586 | 343396 | 201230056 | 24.2074 | 8.3682 |
| 522 | 272484 | 142236648 | 22.8473 | 8.0517 | 587 | 344569 | 202262003 | 24.2281 | 8.3730 |
| 523 | 273529 | 143055667 | 22.8692 | 8.0569 | 588 | 345744 | 203297472 | 24.2487 | 8.3777 |
| 524 | 274576 | 143877824 | 22.8910 | 8.0620 | 589 | 346921 | 204336469 | 24.2693 | 8.3825 |
| 525 | 275625 | 144703125 | 22.9129 | 8.0671 | 590 | 348100 | 205379000 | 24.2899 | 8.3872 |
| 526 | 276676 | 145531576 | 22.9347 | 8.0723 | 591 | 349281 | 206425071 | 24.3105 | 8.3919 |
| 527 | 277729 | 146363183 | 22.9565 | 8.0774 | 592 | 350464 | 207474688 | 24.3311 | 8.3967 |
| 528 | 278784 | 147197952 | 22.9783 | 8.0825 | 593 | 351649 | 208527857 | 24.3516 | 8.4014 |
| 529 | 279841 | 148035889 | 23. | 8.0876 | 594 | 352836 | 209584584 | 24.3721 | 8.4061 |
| 530 | 280900 | 148877000 | 23.0217 | 8.0927 | 595 | 354025 | 210644875 | 24.3926 | 8.4108 |
| 531 | 281961 | 149721291 | 23.0434 | 8.0978 | 596 | 355216 | 211708736 | 24.4131 | 8.4155 |
| 532 | 283024 | 150568768 | 23.0651 | 8.1028 | 597 | 356409 | 212776173 | 24.4336 | 8.4202 |
| 533 | 284089 | 151419437 | 23.0868 | 8.1079 | 598 | 357604 | 213847192 | 24.4540 | 8.4249 |
| 534 | 285156 | 152273304 | 23.1084 | 8.1130 | 599 | 358801 | 214921799 | 24.4745 | 8.4296 |
| 535 | 286225 | 153130375 | 23.1301 | 8.1180 | 600 | 360000 | 216000000 | 24.4949 | 8.4343 |
| 536 | 287296 | 153990656 | 23.1517 | 8.1231 | 601 | 361201 | 217081801 | 24.5153 | 8.4390 |
| 537 | 288369 | 154854153 | 23.1733 | 8.1281 | 602 | 362404 | 218167208 | 24.5357 | 8.4437 |
| 538 | 289444 | 155720872 | 23.1948 | 8.1332 | 603 | 363609 | 219256227 | 24.5561 | 8.4484 |
| 539 | 290521 | 156590819 | 23.2164 | 8.1382 | 604 | 364816 | 220348864 | 24.5764 | 8.4530 |
| 540 | 291600 | 157464000 | 23.2379 | 8.1433 | 605 | 366025 | 221445125 | 24.5967 | 8.4577 |
| 541 | 292681 | 158340421 | 23.2594 | 8.1483 | 606 | 367236 | 222545016 | 24.6171 | 8.4623 |
| 542 | 293764 | 159220088 | 23.2809 | 8.1533 | 607 | 368449 | 223648543 | 24.6374 | 8.4670 |
| 543 | 294849 | 160103007 | 23.3024 | 8.1583 | 608 | 369664 | 224755712 | 24.6577 | 8.4716 |
| 544 | 295936 | 160989184 | 23.3238 | 8.1633 | 609 | 370881 | 225866529 | 24.6779 | 8.4763 |
| 545 | 297025 | 161878625 | 23.3452 | 8.1683 | 610 | 372100 | 226981000 | 24.6982 | 8.4809 |
| 546 | 298116 | 162771336 | 23.3666 | 8.1733 | 611 | 373321 | 228099131 | 24.7184 | 8.4856 |
| 547 | 299209 | 163667323 | 23.3880 | 8.1783 | 612 | 374544 | 229220928 | 24.7386 | 8.4902 |
| 548 | 300304 | 164566592 | 23.4094 | 8.1833 | 613 | 375769 | 230346397 | 24.7588 | 8.4948 |
| 549 | 301401 | 165469149 | 23.4307 | 8.1882 | 614 | 376996 | 231475544 | 24.7790 | 8.4994 |
| 550 | 302500 | 166375000 | 23.4521 | 8.1932 | 615 | 378225 | 232608375 | 24.7992 | 8.5040 |
| 551 | 303601 | 167284151 | 23.4734 | 8.1982 | 616 | 379456 | 233744896 | 24.8193 | 8.5086 |
| 552 | 304704 | 168196608 | 23.4947 | 8.2031 | 617 | 380689 | 234885113 | 24.8395 | 8.5132 |
| 553 | 305809 | 169112377 | 23.5160 | 8.2081 | 618 | 381924 | 236029032 | 24.8596 | 8.5178 |
| 554 | 306916 | 170031464 | 23.5372 | 8.2130 | 619 | 383161 | 237176659 | 24.8797 | 8.5224 |
| 555 | 308025 | 170953875 | 23.5584 | 8.2180 | 620 | 384400 | 238328000 | 24.8998 | 8.5270 |
| 556 | 309136 | 171879616 | 23.5797 | 8.2229 | 621 | 385641 | 239483061 | 24.9199 | 8.5316 |
| 557 | 310249 | 172808693 | 23.6008 | 8.2278 | 622 | 386884 | 240641848 | 24.9399 | 8.5362 |
| 558 | 311364 | 173741112 | 23.6220 | 8.2327 | 623 | 388129 | 241804367 | 24.9600 | 8.5408 |
| 559 | 312481 | 174676879 | 23.6432 | 8.2377 | 624 | 389376 | 242970624 | 24.9800 | 8.5453 |
| 560 | 313600 | 175616000 | 23.6643 | 8.2426 | 625 | 390625 | 244140625 | 25. | 8.5499 |
| 561 | 314721 | 176558481 | 23.6854 | 8.2475 | 626 | 391876 | 245314376 | 25.0200 | 8.5544 |
| 562 | 315844 | 177504328 | 23.7065 | 8.2524 | 627 | 393129 | 246491883 | 25.0400 | 8.5590 |
| 563 | 316969 | 178453547 | 23.7276 | 8.2573 | 628 | 394384 | 247673152 | 25.0599 | 8.5635 |
| 564 | 318096 | 179406144 | 23.7487 | 8.2621 | 629 | 395641 | 248858189 | 25.0799 | 8.5681 |
| 565 | 319225 | 180362125 | 23.7697 | 8.2670 | 630 | 396900 | 250047000 | 25.0998 | 8.5726 |
| 566 | 320356 | 181321496 | 23.7908 | 8.2719 | 631 | 398161 | 251239591 | 25.1197 | 8.5772 |
| 567 | 321489 | 182284263 | 23.8118 | 8.2768 | 632 | 399424 | 252435968 | 25.1396 | 8.5817 |
| 568 | 322624 | 183250432 | 23.8328 | 8.2816 | 633 | 400689 | 253636137 | 25.1595 | 8.5862 |
| 569 | 323761 | 184220009 | 23.8537 | 8.2865 | 634 | 401956 | 254840104 | 25.1794 | 8.5907 |
| 570 | 324900 | 185193000 | 23.8747 | 8.2913 | 635 | 403225 | 256047875 | 25.1992 | 8.5952 |
| 571 | 326041 | 186169411 | 23.8956 | 8.2962 | 636 | 404496 | 257259456 | 25.2190 | 8.5997 |
| 572 | 327184 | 187149248 | 23.9165 | 8.3010 | 637 | 405769 | 258474853 | 25.2389 | 8.6043 |
| 573 | 328329 | 188132517 | 23.9374 | 8.3059 | 638 | 407044 | 259694072 | 25.2587 | 8.6088 |
| 574 | 329476 | 189119224 | 23.9583 | 8.3107 | 639 | 408321 | 260917119 | 25.2784 | 8.6132 |
| 575 | 330625 | 190109375 | 23.9792 | 8.3155 | 640 | 409600 | 262144000 | 25.2982 | 8.6177 |

## TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000—(CONTINUED.)

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 641 | 410881 | 263374721 | 25.3180 | 8.6222 | 706 | 498436 | 351895816 | 26.5707 | 8.9043 |
| 642 | 412164 | 264609288 | 25.3377 | 8.6267 | 707 | 499849 | 353393243 | 26.5895 | 8.9085 |
| 643 | 413449 | 265847707 | 25.3574 | 8.6312 | 708 | 501264 | 354894912 | 26.6083 | 8.9127 |
| 644 | 414736 | 267089984 | 25.3772 | 8.6357 | 709 | 502681 | 356400829 | 26.6271 | 8.9169 |
| 645 | 416025 | 268336125 | 25.3969 | 8.6401 | 710 | 504100 | 357911000 | 26.6458 | 8.9211 |
| 646 | 417316 | 269586136 | 25.4165 | 8.6446 | 711 | 505521 | 359425431 | 26.6646 | 8.9253 |
| 647 | 418609 | 270840023 | 25.4362 | 8.6490 | 712 | 506944 | 360944128 | 26.6833 | 8.9295 |
| 648 | 419904 | 272097792 | 25.4558 | 8.6535 | 713 | 508369 | 362467097 | 26.7021 | 8.9337 |
| 649 | 421201 | 273359449 | 25.4755 | 8.6579 | 714 | 509796 | 363994344 | 26.7208 | 8.9378 |
| 650 | 422500 | 274625000 | 25.4951 | 8.6624 | 715 | 511225 | 365525875 | 26.7395 | 8.9420 |
| 651 | 423801 | 275894451 | 25.5147 | 8.6668 | 716 | 512656 | 367061696 | 26.7582 | 8.9462 |
| 652 | 425104 | 277167808 | 25.5343 | 8.6713 | 717 | 514089 | 368601813 | 26.7769 | 8.9503 |
| 653 | 426409 | 278445077 | 25.5539 | 8.6757 | 718 | 515524 | 370146232 | 26.7955 | 8.9545 |
| 654 | 427716 | 279726264 | 25.5734 | 8.6801 | 719 | 516961 | 371694959 | 26.8142 | 8.9587 |
| 655 | 429025 | 281011375 | 25.5930 | 8.6845 | 720 | 518400 | 373248000 | 26.8328 | 8.9628 |
| 656 | 430336 | 282300416 | 25.6125 | 8.6890 | 721 | 519841 | 374805361 | 26.8514 | 8.9670 |
| 657 | 431649 | 283593393 | 25.6320 | 8.6934 | 722 | 521284 | 376367048 | 26.8701 | 8.9711 |
| 658 | 432964 | 284890312 | 25.6515 | 8.6978 | 723 | 522729 | 377933067 | 26.8887 | 8.9752 |
| 659 | 434281 | 286191179 | 25.6710 | 8.7022 | 724 | 524176 | 379503424 | 26.9072 | 8.9794 |
| 660 | 435600 | 287496000 | 25.6905 | 8.7066 | 725 | 525625 | 381078125 | 26.9258 | 8.9835 |
| 661 | 436921 | 288804781 | 25.7099 | 8.7110 | 726 | 527076 | 382657176 | 26.9444 | 8.9876 |
| 662 | 438244 | 290117528 | 25.7294 | 8.7154 | 727 | 528529 | 384240583 | 26.9629 | 8.9918 |
| 663 | 439569 | 291434247 | 25.7488 | 8.7198 | 728 | 529984 | 385828352 | 26.9815 | 8.9959 |
| 664 | 440896 | 292754944 | 25.7682 | 8.7241 | 729 | 531441 | 387420489 | 27. | 9. |
| 665 | 442225 | 294079625 | 25.7876 | 8.7285 | 730 | 532900 | 389017000 | 27.0185 | 9.0041 |
| 666 | 443556 | 295408296 | 25.8070 | 8.7329 | 731 | 534361 | 390617891 | 27.0370 | 9.0082 |
| 667 | 444889 | 296740963 | 25.8263 | 8.7373 | 732 | 535824 | 392223168 | 27.0555 | 9.0123 |
| 668 | 446224 | 298077632 | 25.8457 | 8.7416 | 733 | 537289 | 393832837 | 27.0740 | 9.0164 |
| 669 | 447561 | 299418309 | 25.8650 | 8.7460 | 734 | 538756 | 395446904 | 27.0924 | 9.0205 |
| 670 | 448900 | 300763000 | 25.8844 | 8.7503 | 735 | 540225 | 397065375 | 27.1109 | 9.0246 |
| 671 | 450241 | 302111711 | 25.9037 | 8.7547 | 736 | 541696 | 398688256 | 27.1293 | 9.0287 |
| 672 | 451584 | 303464448 | 25.9230 | 8.7590 | 737 | 543169 | 400315553 | 27.1477 | 9.0328 |
| 673 | 452929 | 304821217 | 25.9422 | 8.7634 | 738 | 544644 | 401947272 | 27.1662 | 9.0369 |
| 674 | 454276 | 306182024 | 25.9615 | 8.7677 | 739 | 546121 | 403583419 | 27.1846 | 9.0410 |
| 675 | 455625 | 307546875 | 25.9808 | 8.7721 | 740 | 547600 | 405224000 | 27.2029 | 9.0450 |
| 676 | 456976 | 308915776 | 26. | 8.7764 | 741 | 549081 | 406869021 | 27.2213 | 9.0491 |
| 677 | 458329 | 310288733 | 26.0192 | 8.7807 | 742 | 550564 | 408518488 | 27.2397 | 9.0532 |
| 678 | 459684 | 311665752 | 26.0384 | 8.7850 | 743 | 552049 | 410172407 | 27.2580 | 9.0572 |
| 679 | 461041 | 313046839 | 26.0576 | 8.7893 | 744 | 553536 | 411830784 | 27.2764 | 9.0613 |
| 680 | 462400 | 314432000 | 26.0768 | 8.7937 | 745 | 555025 | 413493625 | 27.2947 | 9.0654 |
| 681 | 463761 | 315821241 | 26.0960 | 8.7980 | 746 | 556516 | 415160936 | 27.3130 | 9.0694 |
| 682 | 465124 | 317214568 | 26.1151 | 8.8023 | 747 | 558009 | 416832723 | 27.3313 | 9.0735 |
| 683 | 466489 | 318611987 | 26.1343 | 8.8066 | 748 | 559504 | 418508992 | 27.3496 | 9.0775 |
| 684 | 467856 | 320013504 | 26.1534 | 8.8109 | 749 | 561001 | 420189749 | 27.3679 | 9.0816 |
| 685 | 469225 | 321419125 | 26.1725 | 8.8152 | 750 | 562500 | 421875000 | 27.3861 | 9.0856 |
| 686 | 470596 | 322828856 | 26.1916 | 8.8194 | 751 | 564001 | 423564751 | 27.4044 | 9.0896 |
| 687 | 471969 | 324242703 | 26.2107 | 8.8237 | 752 | 565504 | 425259008 | 27.4226 | 9.0937 |
| 688 | 473344 | 325660672 | 26.2298 | 8.8280 | 753 | 567009 | 426957777 | 27.4408 | 9.0977 |
| 689 | 474721 | 327082769 | 26.2488 | 8.8323 | 754 | 568516 | 428661064 | 27.4591 | 9.1617 |
| 690 | 476100 | 328509000 | 26.2679 | 8.8366 | 755 | 570025 | 430368875 | 27.4773 | 9.1057 |
| 691 | 477481 | 329939371 | 26.2869 | 8.8408 | 756 | 571536 | 432081216 | 27.4955 | .1098 |
| 692 | 478864 | 331373888 | 26.3059 | 8.8451 | 757 | 573049 | 433798093 | 27.5136 | 9.1138 |
| 693 | 480249 | 332812557 | 26.3249 | 8.8493 | 758 | 574564 | 435519512 | 27.5318 | 9.1178 |
| 694 | 481636 | 334255384 | 26.3439 | 8.8536 | 759 | 576081 | 437245479 | 27.5500 | 9.1218 |
| 695 | 483025 | 335702375 | 26.3629 | 8.8578 | 760 | 577600 | 438976000 | 27.5681 | 9.1258 |
| 696 | 484416 | 337153536 | 26.3818 | 8.8621 | 761 | 579121 | 440711081 | 27.5862 | 9.1298 |
| 697 | 485809 | 338608873 | 26.4008 | 8.8663 | 762 | 580644 | 442450728 | 27.6043 | 9.1338 |
| 698 | 487204 | 340068392 | 26.4197 | 8.8706 | 763 | 582169 | 444194947 | 27.6225 | 9.1378 |
| 699 | 488601 | 341532099 | 26.4386 | 8.8748 | 764 | 583696 | 445943744 | 27.6405 | 9.1418 |
| 700 | 490000 | 343000000 | 26.4575 | 8.8790 | 765 | 585225 | 447697125 | 27.6586 | 9.1458 |
| 701 | 491401 | 344472101 | 26.4764 | 8.8833 | 766 | 586756 | 449455096 | 27.6767 | 9.1498 |
| 702 | 492804 | 345948408 | 26.4953 | 8.8875 | 767 | 588289 | 451217663 | 27.6948 | 9.1537 |
| 703 | 494209 | 347428927 | 26.5141 | 8.8917 | 768 | 589824 | 452984832 | 27.7128 | 9.1577 |
| 704 | 495616 | 348913664 | 26.5330 | 8.8959 | 769 | 591361 | 454756609 | 27.7308 | 9.1617 |
| 705 | 497025 | 350402625 | 26.5518 | 8.9001 | 770 | 592900 | 456533000 | 27.7489 | 9.1657 |

**TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000**—(CONTINUED.)

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 771 | 594441 | 458314011 | 27.7669 | 9.1696 | 836 | 698896 | 584277056 | 28.9137 | 9.4204 |
| 772 | 595984 | 460099648 | 27.7849 | 9.1736 | 837 | 700569 | 586376253 | 28.9310 | 9.4241 |
| 773 | 597529 | 461889917 | 27.8029 | 9.1775 | 838 | 702244 | 588480472 | 28.9482 | 9.4279 |
| 774 | 599076 | 463684824 | 27.8209 | 9.1815 | 839 | 703921 | 590589719 | 28.9655 | 9.4316 |
| 775 | 600625 | 465484375 | 27.8388 | 9.1855 | 840 | 705600 | 592704000 | 28.9828 | 9.4354 |
| 776 | 602176 | 467288576 | 27.8568 | 9.1894 | 841 | 707281 | 594823321 | 29. | 9.4391 |
| 777 | 603729 | 469097433 | 27.8747 | 9.1933 | 842 | 708964 | 596947688 | 29.0172 | 9.4429 |
| 778 | 605284 | 470910952 | 27.8927 | 9.1973 | 843 | 710649 | 599077107 | 29.0345 | 9.4466 |
| 779 | 606841 | 472729139 | 27.9106 | 9.2012 | 844 | 712336 | 601211584 | 29.0517 | 9.4503 |
| 780 | 608400 | 474552000 | 27.9285 | 9.2052 | 845 | 714025 | 603351125 | 29.0689 | 9.4541 |
| 781 | 609961 | 476379541 | 27.9464 | 9.2091 | 846 | 715716 | 605495736 | 29.0861 | 9.4578 |
| 782 | 611524 | 478211768 | 27.9643 | 9.2130 | 847 | 717409 | 607645423 | 29.1033 | 9.4615 |
| 783 | 613089 | 480048687 | 27.9821 | 9.2170 | 848 | 719104 | 609800192 | 29.1204 | 9.4652 |
| 784 | 614656 | 481890304 | 28. | 9.2209 | 849 | 720801 | 611960049 | 29.1376 | 9.4690 |
| 785 | 616225 | 483736625 | 28.0179 | 9.2248 | 850 | 722500 | 614125000 | 29.1548 | 9.4727 |
| 786 | 617796 | 485587656 | 28.0357 | 9.2287 | 851 | 724201 | 616295051 | 29.1719 | 9.4764 |
| 787 | 619369 | 487443403 | 28.0535 | 9.2326 | 852 | 725904 | 618470208 | 29.1890 | 9.4801 |
| 788 | 620944 | 489303872 | 28.0713 | 9.2365 | 853 | 727609 | 620650477 | 29.2062 | 9.4838 |
| 789 | 622521 | 491169069 | 28.0891 | 9.2404 | 854 | 729316 | 622835864 | 29.2233 | 9.4875 |
| 790 | 624100 | 493039000 | 28.1069 | 9.2443 | 855 | 731025 | 625026375 | 29.2404 | 9.4912 |
| 791 | 625681 | 494913671 | 28.1247 | 9.2482 | 856 | 732736 | 627222016 | 29.2575 | 9.4949 |
| 792 | 627264 | 496793088 | 28.1425 | 9.2521 | 857 | 734449 | 629422793 | 29.2746 | 9.4986 |
| 793 | 628849 | 498677257 | 28.1603 | 9.2560 | 858 | 736164 | 631628712 | 29.2916 | 9.5023 |
| 794 | 630436 | 500566184 | 28.1780 | 9.2599 | 859 | 737881 | 633839779 | 29.3087 | 9.5060 |
| 795 | 632025 | 502459875 | 28.1957 | 9.2638 | 860 | 739600 | 636056000 | 29.3258 | 9.5097 |
| 796 | 633616 | 504358336 | 28.2135 | 9.2677 | 861 | 741321 | 638277381 | 29.3428 | 9.5134 |
| 797 | 635209 | 506261573 | 28.2312 | 9.2716 | 862 | 743044 | 640503928 | 29.3598 | 9.5171 |
| 798 | 636804 | 508169592 | 28.2489 | 9.2754 | 863 | 744769 | 642735647 | 29.3769 | 9.5207 |
| 799 | 638401 | 510082399 | 28.2666 | 9.2793 | 864 | 746496 | 644972544 | 29.3939 | 9.5244 |
| 800 | 640000 | 512000000 | 28.2843 | 9.2832 | 865 | 748225 | 647214625 | 29.4109 | 9.5281 |
| 801 | 641601 | 513922401 | 28.3019 | 9.2870 | 866 | 749956 | 649461896 | 29.4279 | 9.5317 |
| 802 | 643204 | 515849608 | 28.3196 | 9.2909 | 867 | 751689 | 651714363 | 29.4449 | 9.5354 |
| 803 | 644809 | 517781627 | 28.3373 | 9.2948 | 868 | 753424 | 653972032 | 29.4618 | 9.5391 |
| 804 | 646416 | 519718464 | 28.3549 | 9.2986 | 869 | 755161 | 656234909 | 29.4788 | 9.5427 |
| 805 | 648025 | 521660125 | 28.3725 | 9.3025 | 870 | 756900 | 658503000 | 29.4958 | 9.5464 |
| 806 | 649636 | 523606616 | 28.3901 | 9.3063 | 871 | 758641 | 660776311 | 29.5127 | 9.5501 |
| 807 | 651249 | 525557943 | 28.4077 | 9.3102 | 872 | 760384 | 663054848 | 29.5296 | 9.5537 |
| 808 | 652864 | 527514112 | 28.4253 | 9.3140 | 873 | 762129 | 665338617 | 29.5466 | 9.5574 |
| 809 | 654481 | 529475129 | 28.4429 | 9.3179 | 874 | 763876 | 667627624 | 29.5635 | 9.5610 |
| 810 | 656100 | 531441000 | 28.4605 | 9.3217 | 875 | 765625 | 669921875 | 29.5804 | 9.5647 |
| 811 | 657721 | 533411731 | 28.4781 | 9.3255 | 876 | 767376 | 672221376 | 29.5973 | 9.5683 |
| 812 | 659344 | 535387328 | 28.4956 | 9.3294 | 877 | 769129 | 674526133 | 29.6142 | 9.5719 |
| 813 | 660969 | 537367797 | 28.5132 | 9.3332 | 878 | 770884 | 676836152 | 29.6311 | 9.5756 |
| 814 | 662596 | 539353144 | 28.5307 | 9.3370 | 879 | 772641 | 679151439 | 29.6479 | 9.5792 |
| 815 | 664225 | 541343375 | 28.5482 | 9.3408 | 880 | 774400 | 681472000 | 29.6648 | 9.5828 |
| 816 | 665856 | 543338496 | 28.5657 | 9.3447 | 881 | 776161 | 683797841 | 29.6816 | 9.5865 |
| 817 | 667489 | 545338513 | 28.5832 | 9.3485 | 882 | 777924 | 686128968 | 29.6985 | 9.5901 |
| 818 | 669124 | 547343432 | 28.6007 | 9.3523 | 883 | 779689 | 688465387 | 29.7153 | 9.5937 |
| 819 | 670761 | 549353259 | 28.6182 | 9.3561 | 884 | 781456 | 690807104 | 29.7321 | 9.5973 |
| 820 | 672400 | 551368000 | 28.6356 | 9.3599 | 885 | 783225 | 693154125 | 29.7489 | 9.6010 |
| 821 | 674041 | 553387661 | 28.6531 | 9.3637 | 886 | 784996 | 695506456 | 29.7658 | 9.6046 |
| 822 | 675684 | 555412248 | 28.6705 | 9.3675 | 887 | 786769 | 697864103 | 29.7825 | 9.6082 |
| 823 | 677329 | 557441767 | 28.6880 | 9.3713 | 888 | 788544 | 700227072 | 29.7993 | 9.6118 |
| 824 | 678976 | 559476224 | 28.7054 | 9.3751 | 889 | 790321 | 702595369 | 29.8161 | 9.6154 |
| 825 | 680625 | 561515625 | 28.7228 | 9.3789 | 890 | 792100 | 704969000 | 29.8329 | 9.6190 |
| 826 | 682276 | 563559976 | 28.7402 | 9.3827 | 891 | 793881 | 707347971 | 29.8496 | 9.6226 |
| 827 | 683929 | 565609283 | 28.7576 | 9.3865 | 892 | 795664 | 709732288 | 29.8664 | 9.6262 |
| 828 | 685584 | 567663552 | 28.7750 | 9.3902 | 893 | 797449 | 712121957 | 29.8831 | 9.6298 |
| 829 | 687241 | 569722789 | 28.7924 | 9.3940 | 894 | 799236 | 714516984 | 29.8998 | 9.6334 |
| 830 | 688900 | 571787000 | 28.8097 | 9.3978 | 895 | 801025 | 716917375 | 29.9166 | 9.6370 |
| 831 | 690561 | 573856191 | 28.8271 | 9.4016 | 896 | 802816 | 719323136 | 29.9333 | 9.6406 |
| 832 | 692224 | 575930368 | 28.8444 | 9.4053 | 897 | 804609 | 721734273 | 29.9500 | 9.6442 |
| 833 | 693889 | 578009537 | 28.8617 | 9.4091 | 898 | 806404 | 724150792 | 29.9666 | 9.6477 |
| 834 | 695556 | 580093704 | 28.8791 | 9.4129 | 899 | 808201 | 726572699 | 29.9833 | 9.6513 |
| 835 | 697225 | 582182875 | 28.8964 | 9.4166 | 900 | 810000 | 729000000 | 30. | 9.6549 |

## TABLE of Squares, Cubes, Square Roots, and Cube Roots, of Numbers from 1 to 1000—(CONTINUED.)

| No. | Square. | Cube. | Sq. Rt. | C. Rt. | No. | Square. | Cube. | Sq. Rt. | C. Rt. |
|---|---|---|---|---|---|---|---|---|---|
| 901 | 811801 | 731432701 | 30.0167 | 9.6585 | 951 | 904401 | 860085351 | 30.8383 | 9.8339 |
| 902 | 813604 | 733870808 | 30.0333 | 9.6620 | 952 | 906304 | 862801408 | 30.8545 | 9.8374 |
| 903 | 815409 | 736314327 | 30.0500 | 9.6656 | 953 | 908209 | 865523177 | 30.8707 | 9.8408 |
| 904 | 817216 | 738763264 | 30.0666 | 9.6692 | 954 | 910116 | 868250664 | 30.8869 | 9.8443 |
| 905 | 819025 | 741217625 | 30.0832 | 9.6727 | 955 | 912025 | 870983875 | 30.9031 | 9.8477 |
| 906 | 820836 | 743677416 | 30.0998 | 9.6763 | 956 | 913936 | 873722816 | 30.9192 | 9.8511 |
| 907 | 822649 | 746142643 | 30.1164 | 9.6799 | 957 | 915849 | 876467493 | 30.9354 | 9.8546 |
| 908 | 824464 | 748613312 | 30.1330 | 9.6834 | 958 | 917764 | 879217912 | 30.9516 | 9.8580 |
| 909 | 826281 | 751089429 | 30.1496 | 9.6870 | 959 | 919681 | 881974079 | 30.9677 | 9.8614 |
| 910 | 828100 | 753571000 | 30.1662 | 9.6905 | 960 | 921600 | 884736000 | 30.9839 | 9.8648 |
| 911 | 829921 | 756058031 | 30.1828 | 9.6941 | 961 | 923521 | 887503681 | 31. | 9.8683 |
| 912 | 831744 | 758550528 | 30.1993 | 9.6976 | 962 | 925444 | 890277128 | 31.0161 | 9.8717 |
| 913 | 833569 | 761048497 | 30.2159 | 9.7012 | 963 | 927369 | 893056347 | 31.0322 | 9.8751 |
| 914 | 835396 | 763551944 | 30.2324 | 9.7047 | 964 | 929296 | 895841344 | 31.0483 | 9.8785 |
| 915 | 837225 | 766060875 | 30.2490 | 9.7082 | 965 | 931225 | 898632125 | 31.0644 | 9.8819 |
| 916 | 839056 | 768575296 | 30.2655 | 9.7118 | 966 | 933156 | 901428696 | 31.0805 | 9.8854 |
| 917 | 840889 | 771095213 | 30.2820 | 9.7153 | 967 | 935089 | 904231063 | 31.0966 | 9.8888 |
| 918 | 842724 | 773620632 | 30.2985 | 9.7188 | 968 | 937024 | 907039232 | 31.1127 | 9.8922 |
| 919 | 844561 | 776151559 | 30.3150 | 9.7224 | 969 | 938961 | 909853209 | 31.1288 | 9.8956 |
| 920 | 846400 | 778688000 | 30.3315 | 9.7259 | 970 | 940900 | 912673000 | 31.1448 | 9.8990 |
| 921 | 848241 | 781229961 | 30.3480 | 9.7294 | 971 | 942841 | 915498611 | 31.1609 | 9.9024 |
| 922 | 850084 | 783777448 | 30.3645 | 9.7329 | 972 | 944784 | 918330048 | 31.1769 | 9.9058 |
| 923 | 851929 | 786330467 | 30.3809 | 9.7364 | 973 | 946729 | 921167317 | 31.1929 | 9.9092 |
| 924 | 853776 | 788889024 | 30.3974 | 9.7400 | 974 | 948676 | 924010424 | 31.2090 | 9.9126 |
| 925 | 855625 | 791453125 | 30.4138 | 9.7435 | 975 | 950625 | 926859375 | 31.2250 | 9.9160 |
| 926 | 857476 | 794022776 | 30.4302 | 9.7470 | 976 | 952576 | 929714176 | 31.2410 | 9.9194 |
| 927 | 859329 | 796597983 | 30.4467 | 9.7505 | 977 | 954529 | 932574833 | 31.2570 | 9.9227 |
| 928 | 861184 | 799178752 | 30.4631 | 9.7540 | 978 | 956484 | 935441352 | 31.2730 | 9.9261 |
| 929 | 863041 | 801765089 | 30.4795 | 9.7575 | 979 | 958441 | 938313739 | 31.2890 | 9.9295 |
| 930 | 864900 | 804357000 | 30.4959 | 9.7610 | 980 | 960400 | 941192000 | 31.3050 | 9.9329 |
| 931 | 866761 | 806954491 | 30.5123 | 9.7645 | 981 | 962361 | 944076141 | 31.3209 | 9.9363 |
| 932 | 868624 | 809557568 | 30.5287 | 9.7680 | 982 | 964324 | 946966168 | 31.3369 | 9.9396 |
| 933 | 870489 | 812166237 | 30.5450 | 9.7715 | 983 | 966289 | 949862087 | 31.3528 | 9.9430 |
| 934 | 872356 | 814780504 | 30.5614 | 9.7750 | 984 | 968256 | 952763904 | 31.3688 | 9.9464 |
| 935 | 874225 | 817400375 | 30.5778 | 9.7785 | 985 | 970225 | 955671625 | 31.3847 | 9.9497 |
| 936 | 876096 | 820025856 | 30.5941 | 9.7819 | 986 | 972196 | 958585256 | 31.4006 | 9.9531 |
| 937 | 877969 | 822656953 | 30.6105 | 9.7854 | 987 | 974169 | 961504803 | 31.4166 | 9.9565 |
| 938 | 879844 | 825293672 | 30.6268 | 9.7889 | 988 | 976144 | 964430272 | 31.4325 | 9.9598 |
| 939 | 881721 | 827936019 | 30.6431 | 9.7924 | 989 | 978121 | 967361669 | 31.4484 | 9.9632 |
| 940 | 883600 | 830584000 | 30.6594 | 9.7959 | 990 | 980100 | 970299000 | 31.4643 | 9.9666 |
| 941 | 885481 | 833237621 | 30.6757 | 9.7993 | 991 | 982081 | 973242271 | 31.4802 | 9.9699 |
| 942 | 887364 | 835896888 | 30.6920 | 9.8028 | 992 | 984064 | 976191488 | 31.4960 | 9.9733 |
| 943 | 889249 | 838561807 | 30.7083 | 9.8063 | 993 | 986049 | 979146657 | 31.5119 | 9.9766 |
| 944 | 891136 | 841232384 | 30.7246 | 9.8097 | 994 | 988036 | 982107784 | 31.5278 | 9.9800 |
| 945 | 893025 | 843908625 | 30.7409 | 9.8132 | 995 | 990025 | 985074875 | 31.5436 | 9.9833 |
| 946 | 894916 | 846590536 | 30.7571 | 9.8167 | 996 | 992016 | 988047936 | 31.5595 | 9.9866 |
| 947 | 896809 | 849278123 | 30.7734 | 9.8201 | 997 | 994009 | 991026973 | 31.5753 | 9.9900 |
| 948 | 898704 | 851971392 | 30.7896 | 9.8236 | 998 | 996004 | 994011992 | 31.5911 | 9.9933 |
| 949 | 900601 | 854670349 | 30.8058 | 9.8270 | 999 | 998001 | 997002999 | 31.6070 | 9.9967 |
| 950 | 902500 | 857375000 | 30.8221 | 9.8305 | 1000 | 1000000 | 1000000000 | 31.6228 | 10. |

**To find the square or cube of any whole number ending with ciphers.** First, omit all the final ciphers. Take from the table the square or cube (as the case may be) of the rest of the number. To this *square* add *twice* as many ciphers as there were final ciphers in the original number. To the *cube* add *three* times as many as in the original number. Thus, for $90500^2$; $905^2 = 819025$. Add twice 2 ciphers, obtaining 8190250000. For $90500^3$, $905^3 = 741217625$. Add 3 times 2 ciphers, obtaining 741217625000000.

# TABLE XXX. THE TRUE MERIDIAN AND THE MAGNETIC DECLINATION.

The method given below, and Tables *A* and *B* following, have been adapted from the 1914 issue of "Principal Facts of the Earth's Magnetism," published by the U. S. Coast and Geodetic Survey.

## Determination of (1) The True Meridian with a Transit by Observations on Polaris at Elongation; (2) The Magnetic Declination.

1. (*a*) Twenty or thirty minutes before elongation, as found from Table *A*, set up the transit over a previously placed hub.

(*b*) Bring the vertical wire upon Polaris, which will appear to move to the right for eastern and to the left for western elongation, except shortly before and after elongation.

(*c*) Using the tangent screw of vernier plate, bisect the star until no further lateral motion is apparent.

(*d*) Depress the telescope to the horizontal and sight a strongly illuminated plumb line or pencil held vertically over or upon a piece of 2×4-inch lumber, 300 or 400 feet north of instrument, which has been previously so set and firmly held in a horizontal east-west position that the mark sighted will be sure to fall upon it when the star is at elongation, and bring the illuminated object precisely into the line of sight. Mark on the 2×4 the point thus found. Quickly revolve the vernier plate about 180°, repeat the operation and bisect the distance between the two points thus located on the 2×4. A line joining this point with the transit hub will lie in the vertical plane through the instrument and the star at elongation.

(*e*) By daylight lay off to east or west, as required, the azimuth taken from Table *B* for the latitude of the place; the line of sight will then define the true meridian. Set monuments if wanted for future reference.

2. The magnetic declination is found by reading the north end of needle on the compass circle when its zero lies in the vertical plane of the line of sight, while this is in the true meridian. To determine the mean daily declination find the mean of a set of declination readings taken at intervals throughout the day.

## TABLE XXX.—Table A. Local Mean (Astronomical) Time of the Culminations and Elongations of Polaris in the Year 1915.

(For Latitude 40° North and Longitude 90° West of Greenwich).

| Date. | East Elong. | | Upper Culmin. | | West Elong. | | Lower Culmin. | |
|---|---|---|---|---|---|---|---|---|
| | h | m | h | m | h | m | h | m |
| Jan 1 | 0 | 51.7 | 6 | 46.9 | 12 | 42.1 | 18 | 44.9 |
| Jan. 15 | 23 | 52.5 | 5 | 51.6 | 11 | 46.8 | 17 | 49.6 |
| Feb. 1 | 22 | 45.3 | 4 | 44.5 | 10 | 39.7 | 16 | 42.5 |
| Feb. 15 | 21 | 50.1 | 3 | 49.2 | 9 | 44.4 | 15 | 47.2 |
| Mar. 1 | 20 | 54.8 | 2 | 54.0 | 8 | 49.2 | 14 | 52.0 |
| Mar. 15 | 19 | 59.6 | 1 | 58.8 | 7 | 54.0 | 13 | 56.8 |
| Apr. 1 | 18 | 52.7 | 0 | 51.9 | 6 | 47.1 | 12 | 49.9 |
| Apr. 15 | 17 | 57.7 | 23 | 52.9 | 5 | 52.0 | 11 | 54.8 |
| May 1 | 16 | 54.8 | 22 | 50.0 | 4 | 49.2 | 10 | 52.0 |
| May 15 | 15 | 59.9 | 21 | 55.1 | 3 | 54.2 | 9 | 57.0 |
| June 1 | 14 | 53.3 | 20 | 48.5 | 2 | 47.6 | 8 | 50.4 |
| June 15 | 13 | 58.5 | 19 | 53.7 | 1 | 52.8 | 7 | 55.6 |
| July 1 | 12 | 55.9 | 18 | 51.1 | 0 | 50.2 | 6 | 53.0 |
| July 15 | 12 | 01.1 | 17 | 56.3 | 23 | 51.5 | 5 | 58.2 |
| Aug. 1 | 10 | 54.5 | 16 | 49.7 | 22 | 44.9 | 4 | 51.7 |
| Aug. 15 | 9 | 59.8 | 15 | 55.0 | 21 | 50.2 | 3 | 56.9 |
| Sep. 1 | 8 | 53.2 | 14 | 48.4 | 20 | 43.6 | 2 | 50.3 |
| Sep. 15 | 7 | 58.3 | 13 | 53.5 | 19 | 48.7 | 1 | 55.4 |
| Oct. 1 | 6 | 55.5 | 12 | 50.7 | 18 | 45.9 | 0 | 52.7 |
| Oct. 15 | 6 | 00.6 | 11 | 55.8 | 17 | 51.0 | 23 | 53.8 |
| Nov. 1 | 4 | 53.7 | 10 | 48.9 | 16 | 44.1 | 22 | 46.9 |
| Nov. 15 | 3 | 58.6 | 9 | 53.8 | 15 | 49.0 | 21 | 51.8 |
| Dec. 1 | 2 | 55.6 | 8 | 50.8 | 14 | 46.0 | 20 | 48.8 |
| Dec. 15 | 2 | 00.4 | 7 | 55.6 | 13 | 50.8 | 19 | 53.6 |

For any calendar day other than the 1st or 15th, subtract the correction from the tabular quantities for the preceding date.

| Day of Month. | Elapsed Days. | Corr., Min. |
|---|---|---|
| 2 or 16 | 1 | 3.9 |
| 3 17 | 2 | 7.8 |
| 4 18 | 3 | 11.8 |
| 5 19 | 4 | 15.7 |
| 6 20 | 5 | 19.6 |
| 7 21 | 6 | 23.5 |
| 8 22 | 7 | 27.4 |
| 9 23 | 8 | 31.4 |
| 10 24 | 9 | 35.3 |
| 11 25 | 10 | 39.2 |
| 12 26 | 11 | 43.1 |
| 13 27 | 12 | 47.0 |
| 14 28 | 13 | 51.0 |
| 29 | 14 | 54.9 |
| 30 | 15 | 58.8 |
| 31 | 16 | 62.7 |

*A*. To refer above tabular quantities to any year other than 1915, add or subtract (as indicated by + or − signs) the number of minutes shown below for the respective years:

1916: +1.6 up to March 1; −2.3 on and after March 1.
1917: −0.7; 1918: +0.9; 1919: +2.5.
1920: +4.0 up to March 1; −0.1 on and after March 1.
1921: +1.6; 1922: +3.1; 1923: +4.5.
1924: +5.9 up to March 1; +2.0 on and after March 1.
1925: +3.3; 1926: +4.6; 1927: +5.9.
1928: +7.2 up to March 1; +3.3 on and after March 1.

*B*. To refer the table to *standard* time and to the civil day:

(*a*) For each degree of longitude west of the 90th meridian add 4, and for each degree east subtract 4, minutes from the tabular quantities.

(*b*) The astronomical day begins twelve hours *after* the civil day of same date. Thus, 14 h. 52 m. March 15 astronomical is 2:52 A.M. March 16 civil time.

Two eastern elongations occur on Jan. 14, 1915, and two western elongations on July 13, 1915: two upper culminations occur on April 14, and two lower culminations on October 14. Upper and lower culmination, are separated by 11 h. 58.0 m.

*C*. For every degree of latitude south of 40° add 0.1 m. for west elongation, and for every degree north of 40° subtract 0.16 m. Reverse these operations for east elongations.

*D*. For every 15° of longitude east of 90° add 0.16 m., and for every 15° west of 90° subtract 0.16 m.

## TABLE XXX.—Table B. Azimuth of Polaris at Elongation for Each Year from 1917 to 1928.

| Lat. | 1917 | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 | 1926 | 1927 | 1928 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| 10 | 1 09.3 | 1 09.0 | 1 08.7 | 1 08.4 | 1 08.1 | 1 07.8 | 1 07.4 | 1 07.2 | 1 06.8 | 1 06.5 | 1 06.2 | 1 05.9 |
| 12 | 09.8 | 09.5 | 09.2 | 08.9 | 08.6 | 08.2 | 07.9 | 07.6 | 07.3 | 07.1 | 06.7 | 06.4 |
| 14 | 10.4 | 10.0 | 09.7 | 09.4 | 09.1 | 08.8 | 08.5 | 08.2 | 07.8 | 07.5 | 07.2 | 06.9 |
| 16 | 11.0 | 10.7 | 10.4 | 10.1 | 09.8 | 09.4 | 09.1 | 08.8 | 08.5 | 08.2 | 07.8 | 07.5 |
| 18 | 11.8 | 11.5 | 11.1 | 10.7 | 10.5 | 10.2 | 09.8 | 09.5 | 09.2 | 08.9 | 08.6 | 08.2 |
| 20 | 12.7 | 12.3 | 12.0 | 11.7 | 11.4 | 11.0 | 10.7 | 10.0 | 10.0 | 09.7 | 09.4 | 09.1 |
| 21 | 13.1 | 12.8 | 12.5 | 12.2 | 11.8 | 11.5 | 11.2 | 10.8 | 10.5 | 10.2 | 09.8 | 09.5 |
| 22 | 13.6 | 13.3 | 13.0 | 12.6 | 12.3 | 12.0 | 11.6 | 11.3 | 11.0 | 10.6 | 10.3 | 10.0 |
| 23 | 14.2 | 13.8 | 13.5 | 13.2 | 12.8 | 12.5 | 12.2 | 11.8 | 11.5 | 11.2 | 10.8 | 10.5 |
| 24 | 14.7 | 14.4 | 14.1 | 13.7 | 13.4 | 13.0 | 12.7 | 12.4 | 12.0 | 11.7 | 11.4 | 11.0 |
| 25 | 15.3 | 15.0 | 14.7 | 14.3 | 14.0 | 13.6 | 13.3 | 13.0 | 12.6 | 12.3 | 11.9 | 11.6 |
| 26 | 16.0 | 15.6 | 15.3 | 14.9 | 14.7 | 14.2 | 13.9 | 13.6 | 13.2 | 12.9 | 12.5 | 12.2 |
| 27 | 16.6 | 16.3 | 15.9 | 15.6 | 15.2 | 14.9 | 14.6 | 14.2 | 13.9 | 13.5 | 13.2 | 12.8 |
| 28 | 17.3 | 17.0 | 16.6 | 16.3 | 15.9 | 15.6 | 15.2 | 14.9 | 14.6 | 14.2 | 13.8 | 13.5 |
| 29 | 18.1 | 17.7 | 17.4 | 17.0 | 16.6 | 16.3 | 16.0 | 15.6 | 15.2 | 14.9 | 14.6 | 14.2 |
| 30 | 18.8 | 18.5 | 18.1 | 17.8 | 17.4 | 17.0 | 16.7 | 16.4 | 16.0 | 15.6 | 15.3 | 14.9 |
| 31 | 19.7 | 19.3 | 18.9 | 18.6 | 18.2 | 17.9 | 17.5 | 17.2 | 16.8 | 16.4 | 16.1 | 15.7 |
| 32 | 20.5 | 20.1 | 19.8 | 19.4 | 19.1 | 18.7 | 18.3 | 18.0 | 17.6 | 17.2 | 16.9 | 16.5 |
| 33 | 21.4 | 21.0 | 20.7 | 20.3 | 19.9 | 19.6 | 19.2 | 18.8 | 18.5 | 18.1 | 17.8 | 17.4 |
| 34 | 22.4 | 22.0 | 21.6 | 21.2 | 20.9 | 20.5 | 20.1 | 19.8 | 19.4 | 19.0 | 18.6 | 18.3 |
| 35 | 23.3 | 23.0 | 22.6 | 22.2 | 21.8 | 21.5 | 21.1 | 20.7 | 20.4 | 20.0 | 19.6 | 19.2 |
| 36 | 24.4 | 24.0 | 23.6 | 23.3 | 22.9 | 22.5 | 22.1 | 21.7 | 21.4 | 21.0 | 20.6 | 20.2 |
| 37 | 25.3 | 25.1 | 24.7 | 24.3 | 24.0 | 23.6 | 23.2 | 22.8 | 22.4 | 22.0 | 21.6 | 21.3 |
| 38 | 26.6 | 26.2 | 25.9 | 25.5 | 25.1 | 24.7 | 24.3 | 23.9 | 23.5 | 23.2 | 22.8 | 22.4 |
| 39 | 27.8 | 27.5 | 27.1 | 26.7 | 26.3 | 25.8 | 25.5 | 25.1 | 24.7 | 24.3 | 23.9 | 23.5 |
| 40 | 29.1 | 28.7 | 28.3 | 27.9 | 27.5 | 27.1 | 26.7 | 26.3 | 25.9 | 25.5 | 25.1 | 24.7 |
| 41 | 30.4 | 30.0 | 29.6 | 29.1 | 28.8 | 28.4 | 28.0 | 27.6 | 27.2 | 26.8 | 26.4 | 26.0 |
| 42 | 31.9 | 31.5 | 31.0 | 30.6 | 30.2 | 29.8 | 29.4 | 29.0 | 28.6 | 28.2 | 27.8 | 27.3 |
| 43 | 33.4 | 32.9 | 32.5 | 32.1 | 31.8 | 31.2 | 30.8 | 30.4 | 30.0 | 29.6 | 29.1 | 28.7 |
| 44 | 34.9 | 34.5 | 34.1 | 33.6 | 33.2 | 32.8 | 32.4 | 31.9 | 31.5 | 31.1 | 30.6 | 30.2 |
| 45 | 36.6 | 36.1 | 35.7 | 35.3 | 34.8 | 34.4 | 34.0 | 33.5 | 33.1 | 32.6 | 32.2 | 31.8 |
| 46 | 38.3 | 37.8 | 37.4 | 37.0 | 36.5 | 36.1 | 35.6 | 35.2 | 34.8 | 34.3 | 33.9 | 33.4 |
| 47 | 40.1 | 39.7 | 39.2 | 38.8 | 38.3 | 37.9 | 37.4 | 37.0 | 36.5 | 36.1 | 35.6 | 35.2 |
| 48 | 42.0 | 41.6 | 41.1 | 40.7 | 40.2 | 39.8 | 39.3 | 38.8 | 38.4 | 37.9 | 37.4 | 37.0 |
| 49 | 44.1 | 43.6 | 43.1 | 42.7 | 42.2 | 41.7 | 41.3 | 40.8 | 40.3 | 39.9 | 39.4 | 38.9 |
| 50 | 1 46.2 | 1 45.7 | 1 45.3 | 1 44.8 | 1 44.3 | 1 43.8 | 1 43.4 | 1 42.9 | 1 42.4 | 1 41.9 | 1 41.4 | 1 41.0 |

**Remarks.**

This table was computed with the mean declination of Polaris for each year. A more accurate result will be had by applying to the tabular values the following corrections, which depend on the difference of the mean and the apparent place of the star. The deduced azimuth will, in general, be correct within 0′.3.

| For the middle of | Correction. |
|---|---|
| January | —0′.5 |
| February | —0′.4 |
| March | —0′.3 |
| April | 0′.0 |
| May | +0′.1 |
| June | +0′.2 |
| July | +0′.2 |
| August | +0′.1 |
| September | —0′.1 |
| October | —0′.4 |
| November | —0′.6 |
| December | —0′.8 |

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